(12) LEVEL III

AD-E500 128

Copy 23 of 48 copies

IDA STUDY S-506

# PRICING AND COST ALLOCATION FOR AUTOVON

William F. Beazer

March 1979



*Prepared for*

Defense Communications Agency



IDA

INSTITUTE FOR DEFENSE ANALYSES
PROGRAM ANALYSIS DIVISION

The work reported in this document was conducted under Contract DAHC 15 73 C 0200 for the Defense Communications Agency. The publication of this IDA Study does not indicate endorsement by the Defense Communications Agency, nor should the contents be construed as reflecting the official opinion of that agency.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. AD-A083 544 |
| | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) PRICING AND COST ALLOCATION FOR AUTOVON | 5. TYPE OF REPORT & PERIOD COVERED FINAL |
| | 6. PERFORMING ORG. REPORT NUMBER IDA STUDY S-506 |
| 7. AUTHOR(s) William F. Beazer | 8. CONTRACT OR GRANT NUMBER(s) DAHC 15 73 C 0200 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for Defense Analyses 400 Army-Navy Drive Arlington, VA 22202 | 10. PROGRAM ELEMENT PROJECT TASK AREA & WORK UNIT NUMBERS DCA T-652-3 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Defense Communications Agency (670) 9th and Courthouse Road Arlington, VA 22201 | 12. REPORT DATE March 1979 |
| | 13. NUMBER OF PAGES 96 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | 15. SECURITY CLASS (of this report) UNCLASSIFIED |
| | 15a. DECLASSIFICATION DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cost allocation, Usage rates, AUTOVON, Rate structure, Congestion, Subscriber behavior, Precedence.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study analyzes the current rate structure of AUTOVON and the way in which costs are allocated among users as defined in broad categories. It makes recommendations about ways in which cost allocation might be improved, examines the problem of congestion under the current rate structure, and the effects on cost allocation and subscriber behavior of adopting a price scheme based on usage. A methodology is developed for calculating appropriate usage charges relative to distance and holding time.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

IDA STUDY S-506

# PRICING AND COST ALLOCATION FOR AUTOVON

William F. Beazer

March 1979

INSTITUTE FOR DEFENSE ANALYSES
PROGRAM ANALYSIS DIVISION
400 Army-Navy Drive, Arlington, Virginia 22202

DAHC15 73 C 0200
Task Order 652-3

# PREFACE

This study was prepared under a contract with the Defense Communications Agency (DCA). DCA was interested in an evaluation of the ways in which AUTODIN and AUTOVON services are priced, as well as an analysis of the value and potential cost to subscribers of instituting usage-sensitive pricing for long haul communications. The original effort in Task 652-1 resulted in an IDA study[1] which addressed primarily the pricing of AUTODIN. This effort (Task 652-3) is an extension of that study with additional specific attention to AUTOVON pricing.

The study analyzes the current rate structure and the way in which it allocates costs among users as defined in broad categories. It also makes some recommendations about the way in which cost allocation might be improved through relatively minor adjustments in current rates. The problem of congestion under the current rate structure is examined and the potential effects on congestion, cost allocation and subscriber behavior of adopting a pricing scheme based on usage are discussed at length. A methodology is developed for calculating appropriate usage charges related to distance and holding time. Various ways of charging for precedence are also analyzed.

---

[1] *Cost Allocation for AUTODIN: An Economic Analysis,* Beazer et.al., in 2 volumes, IDA S-487, Institute for Defense Analyses, Arlington, VA: September 1977.

CONTENTS

APPENDICES



FIGURES



TABLES

# EXECUTIVE SUMMARY

This report analyzes the problem of allocating costs and determining rates for the Automatic Voice Network (AUTOVON). The study is divided into four chapters. The first describes AUTOVON and the present rate structure and analyzes the way in which system costs are distributed among users. The second discusses the principles of usage-sensitive pricing and how its introduction might be expected to affect the behavior of agencies and individuals as well as the allocation of costs among users. The third chapter describes the data requirements and the methodology for calculating charges per call within CONUS as a function of distance, holding time and precedence. It also discusses the implications of the fact that DCA cannot affect the individuals who actually place calls, regardless of the kind of charge system instituted. The final chapter contains conclusions and recommendations.

There are a number of observations we can make about the current connectivity fee charge system and about the advisability of adopting a usage charge system. We list these observations with some brief explanations.

## A. THE CURRENT RATE STRUCTURE

- The average charges for different service capabilities currently do not reflect the costs of providing those capabilities. The total revenue collected from users with only area capability does not cover the cost of providing area service; the total revenue collected from users with area-plus and global capabilities exceeds the cost of providing these capabilities.

For example, CONUS subscribers pay 89 percent of their costs, and Pacific subscribers pay 64 percent. On the other hand, CONUS-Europe and CONUS-Pacific subscribers pay approximately one-third more than their costs and global subscribers pay 25 percent more.

- Precedence charges serve primarily to allocate the costs of overseas service. Nearly 80 percent of the area-plus and 91 percent of the global lines are of precedence above priority, while only 9 percent of the CONUS lines are of precedence above priority. The charge per *weighted unit* for a global line is five times that for a CONUS line, but the average charge per global *line* is 15 times that for a CONUS line. High precedence is required to make overseas calls but service is much worse than for lower precedence area calls.

- The current rate structure could easily be adjusted so that, on the average, the costs of different kinds of service are borne by the users of that service. There are a number of ways in which an adjus  .t could be made, such as changing the weighted unit ratios for different levels of precedence. The text illustrates one method which involves calculating a new charge per weighted unit while retaining the precedence ratios. With the new, hypothetical charges, area costs would be paid for by area subscribers and overseas costs would be borne by those with overseas capability.

- One-way-in lines should bear some of the backbone costs. Adding a one-way-in line to an installation that has two-way lines increases the capacity both to take calls off the network and to place outgoing calls. Even though the backbone connection charge is zero, the average annual lease charge paid by the subscriber for a one-way-in line is $2,600. As a result, one-way-in lines are not a free good. The zero backbone charge provides a much greater incentive for users to substitute a one-way-in line for two-way lines (and thus save nearly $3,000) than to add a new line (and incur costs of $2,600).

## B. USAGE SENSITIVE PRICING

- Usage-sensitive pricing has four basic objectives:

  (1) It should induce subscribers to choose the number of access lines and precedence that best suits their traffic requirements.

  (2) It should provide incentives for efficient use of the system.

  (3) It should allocate the costs of the system to the agencies that use it; the billing should also provide information that will permit agencies, if they wish, to shift the costs to or impose controls or regulations on the individuals or agency subdivisions doing the calling.

  (4) It should provide reliable information to the supplier of the service for use in deciding how much capacity is required.

Most of the items that follow address these four points.

- If the monthly backbone charge is very low and nearly all revenues are collected through usage charges, the number and mix of access lines will be more nearly optimal than if connectivity fees are high. At present, users must pay the same amount whether they use a line heavily or very little. As a result, they are more likely to accept a higher level of congestion before acquiring a new access line than they would if access costs were near zero and revenues were collected for usage. In addition, if usage charges were instituted, the rationale for differential charges for two-way and one-way lines would disappear. Selection of the proper mix of lines then would be based upon the technical requirements rather than artificial price differences.

- Charging for usage on the basis of distance, holding time and precedence would allocate costs equitable to each user agency. Adjustments to the present charging system would make it possible to allocate the total costs of a particular category of service, e.g., CONUS, to the entire group of subscribers using that service. Only usage charges, however, will permit

allocation of costs properly to individual agencies or individual lines. Also, usage charges would permit agencies to impose valid controls or restraints on callers. With the current charging system there is little justification or incentive to do so.

- When user charges are zero with all revenues collected through connectivity fees, and capacity is allocated in part by congestion, the supplier of service has imperfect information upon which to base decisions on how much capacity to provide. A portion of the congestion derives from calls that would not be attempted if there were a charge for these calls. Thus, the level of congestion is not a valid standard against which to measure the adequacy of capacity. This point has little relevance for the overseas network where capacity is fixed and independent of congestion. In CONUS, however, capacity is adjusted on the basis of a target level of congestion. If usage charges reduce congestion, they will also permit a reduction in capacity.

- When user charges are zero, total costs, including congestion costs, will exceed the total costs incurred when appropriate usage charges are instituted. The real cost of supplying a given quantity of service is virtually fixed, but, as the price per call charged the user falls below the marginal cost, more low-valued calls will be attempted and the congestion costs imposed upon all callers, particularly those with high-valued calls, will increase.

- The existence of precedence capability reduces the cost of congestion by assuring that high-valued calls are successfully placed. It introduces another cost, however, that is imposed upon those whose conversations are interrupted. The introduction of usage charges for precedence calls would allow the direct costs of precedence calls and the indirect cost of interruptions to be allocated to callers not just on the basis

of capability but also as a function of how many calls they make. Thus there would be an incentive to select lower precedence for calls of lower value as well as for shortening the length of higher precedence calls.

• Charging for usage permits the costs of overseas calls to be allocated to overseas users, regardless of precedence, and permits precedence costs--both the direct costs and the external costs caused by pre-emption--to be allocated to precedence users. Under the current price structure, the majority of the cost of providing overseas service is collected through the charges for precedence. There is no direct relationship between the costs of precedence and the charges for precedence.

• In imposing usage charges, DCA can (a) improve the equity of cost allocation, (b) influence agencies in their choice of numbers and kinds of access lines, and (c) affect only indirectly the behavior of callers. DCA's responsibility is limited to the backbone portion of AUTOVON. It has virtually no control over any activities outside the backbone. Thus, its pricing policies directly affect only the decisions made at the agency level. Changing caller behavior depends upon how the agencies respond to the prices they face and in turn discipline callers or suborganizations to act as though they had to pay the bills.

• Preliminary estimates of the charges per minute that would cover the cost of calls within CONUS indicate that the user fees required would be considerably below those for the FTS and commercial services. For example, our estimated charge per minute for a call of greater than 1,000 miles is 11.1 cents; that recommended for FTS in a recent study done for GSA was 23.9 cents.

There are two main items that this report does not provide: an estimate of the appropriate cost per minute for overseas calls; and data on the cost of installing an Automatic Message Accounting system. Without AMA there is no hope of instituting

the kind of usage charge system we have discussed; however, AMA may be costly, particularly when grafted onto an existing, relatively old network such as AUTOVON. If such an expenditure is justified, it must be less than the value of instituting a usage charge system. Quantifying the values of the benefits we have discussed is difficult, given the relatively small amount of data available, but we have provided a tentative methodology for doing so. The implementation of that methodology awaits a better data base.

When a study is initiated of a complex subject, often more questions are raised than answered. This study is no exception. Among the questions that we feel are worth pursuing are the following:

(1) What advantages and improvements in efficiency would accrue to the government from giving DCA control over the configuration and pricing of access lines as well as the backbone?

(2) What is the best way to price for connectivity to the backbone so that the costs of various types of service are allocated as fairly as possible to its users?

(3) What is the optimal way to price one-way and two-way lines?

(4) What is the magnitude of the congestion costs that system users now support, both for overseas service and and for area service?

(5) What is the magnitude of the problem of pre-emption, both in terms of the number of calls pre-empted at each precedence level and in terms of the cost to the caller of being pre-empted?

(6) To what extent are user agencies interested in obtaining more detailed information on the number of calls made and the costs of calls made by individuals or organizations under their control? Would they use this information, if it were available, to influence the behavior of callers and the costs incurred by the agency?

(7) Is it feasible and are there advantages to integrating AUTOVON with FTS and/or combining it with a network of direct-leased lines and WATTS lines?

(8) What is the cost of instituting AMA? Would partial installation of AMA and gradual expansion of coverage be feasible and cost effective?

## Chapter I

## AUTOVON: CURRENT CHARACTERISTICS AND POTENTIAL IMPROVEMENTS

### A. INTRODUCTION

The Automatic Voice Network (AUTOVON) is the principal long-distance voice communications network within the Defense Communications System. It provides worldwide unsecure direct dial service through a collection of government-owned (overseas) and -leased (US) facilities. AUTOVON was created in 1964 by combining the Army's Switched Circuit Automatic Network with the North American Air Defense Command's Automatic Dial Switching Network. Other networks were subsequently added and the system further expanded.

The term CONUS is applied to the Continental United States including Alaska and Canada. The rest of the world comprises Overseas AUTOVON. Subscribers may select service that is limited to a single area (CONUS) or service covering CONUS plus one overseas area (area plus); or he may select unlimited service (global). The network also features a four-level precedence system composed of--flash override, flash, immediate, and priority; plus the non-precedence routine lines. A precedence call always can interrupt a call of lower precedence if a circuit is needed.

AUTOVON does not provide automatic access to local commercial systems. Some switchboards on which AUTOVON circuits terminate are capable of providing local off-net connections to

long distance callers through an operator; however, the authorities who control the local switchboard at the distant end determine whether off-net calling will be accommodated. Thus, AUTOVON is not an all-purpose system and AUTOVON users make many commercial long-distance toll calls. A number of subscribers also belong to the Federal Telecommunications System (FTS) as well.

AUTOVON is administered by the Defense Communications Agency (DCA) and is financed through a revolving fund, the Communications Services Industrial Fund (CSIF). All operating expenses for the system are paid from the fund, which is then reimbursed by charging user agencies. DCA's authority is limited to the AUTOVON Backbone--the switches and the interconnecting trunks. Subscribers control the access lines from the PBXs and stations to the switches; their decisions on number and type of access lines are based both on cost and on mission requirements.[1] Since costs are important to subscribers, the AUTOVON pricing structure can have considerable influence on the configuration of the access system and on the usage and grade of service that users experience. In brief, the higher the access cost, the fewer the number of access lines subscribers will want and the greater the degree of congestion for a given trunk configuration. Likewise, the lower the cost per call, the less the incentive to reduce the number of calls and the greater (is likely to be) the amount of congestion.

At present, all of the costs of the AUTOVON backbone are collected through access fees which vary as a function of precedence and area coverage. None is collected through metered usage charges. It is the purpose of this paper to examine the potential effects of this pricing policy upon the demand for

[1]A number of studies have recommended that it would be more efficient to have DCA control both the backbone and the access lines. See the DoD *Internal Audit Report (AUTOVON)*, October 12, 1972, and the GAO report *Why Performance of AUTOVON Service Needs Improvement*, September 11, 1974.

access lines and calls, and to evaluate some alternatives that DCA might consider adopting. The alternatives will include both pricing for usage (using calling time, distance and precedence as characteristics to which prices should be applied) and different methods of pricing for access. No final recommendations are presented because many of the alternatives discussed would require the installation of an Automatic Message Accounting System (AMA). We have virtually no information on the cost of installing AMA and, as a result, cannot evaluate whether the benefits of usage pricing are sufficient to offset the AMA costs.

This report is divided into four chapters. Chapter I includes a brief description of the characteristics of AUTOVON and of the current rate-making process. It also examines some of the implications of this structure and proposes changes which, while retaining the current system of charging only for access, would allocate costs more equitably among the agencies as a function of the kinds of services and equipment they use. Chapter II provides a theoretical analysis of various pricing structures. Chapter III offers guidelines for allocating the costs of service if usage charges were to be permitted: it also examines the limited data DCA possesses on the costs of installing AMA. Chapter IV contains conclusions and recommendations.

## B. CHARACTERISTICS OF AUTOVON

Autovon provides world-wide voice communications capabilities to DoD and related agencies through a system of more than 16,000 access lines interconnected by switches and trunk lines. Some of the access lines terminate in single-caller, four-wire phones but the vast majority are connected to manual (PBX) or automatic (PABX) switchboards which service a number of phones and provide access to commercial circuits as well as AUTOVON.

The Defense Communications Agency has the management responsibility for AUTOVON. DCA authority is limited, however,

to the "backbone" consisting of the switching centers and trunk lines. The subscriber agencies lease their access lines directly from commercial carriers.[1] CONUS backbone facilities also are leased from commercial carriers with the lease costs met by DCA from the Communications Services Industrial Fund. The overseas switches are owned by the US Government and the trunks are leased.

An important feature possessed by AUTOVON but not by commercial networks (or the Federal Telephone System) is precedence and pre-emption capability. Every AUTOVON call has an assigned precedence of Flash, Immediate, Priority, or Routine. If no open line is available for a call with precedence above routine, a search is made of the trunks for a line holding a call of lower precedence. If a lower precedence call is found, it is disconnected and the higher precedence call placed. Precedence calls are identified throughout their transmission, and pre-emption can occur at every switch through which the call passes. The extent of the search varies with the precedence level, however, and not all access lines can be pre-empted.

AUTOVON is a command and control network and the precedence and pre-emption capabilities are essential to its operation. It also functions, however, as a dedicated private network for DoD routine business. In CONUS, a majority of the trunks and access lines are required only for routine business, and routine calls are a large proportion of the total. Although precedence and pre-emption are essential, they complicate the required engineering for AUTOVON and make it more difficult, both technically and politically, to share facilities with commercial networks or the Federal Telephone Service.

AUTOVON covers five geographic areas: Alaska, Caribbean, CONUS, Europe and Pacific. With the exception of CONUS, the operational objective for the system world wide is that each

[1]Payments are made through DCA, however.

flash call be completed. This objective is termed flash non-blocking.[1] Within CONUS, two objectives are specified in terms of grade of service (GOS):[2]

(1) Flash calls must complete.

(2) All other calls must have P13 backbone GOS.

A P01 grade of service means that a call has a 99 percent chance of being successfully completed. A P13 backbone GOS means that a call has an 87 percent probability of completing on the backbone network. The probability that the call will be successfully completed is something less than 87 since it also depends upon the availability of both an access line and an open phone once the desired switch is reached.

The prime objective of AUTOVON is to provide reliable and predictable emergency calling capability for flash users. In normal circumstances, the network is used by the full defense community for non-crisis traffic. Within CONUS, the network size and backbone costs are adjusted as call volumes change. In other areas DCA has no authority to configure the network to meet the requirements of non-crisis traffic. Even within CONUS the ability to reconfigure is limited by the overall P13 backbone GOS.

## C. CURRENT RATE STRUCTURE

The Defense Communications Agency must recover each year through charges to the subscriber agencies sufficient payments for the Communications Services Industrial Fund to cover its outlays for voice communications facilities. The billing system for AUTOVON is similar to that which has been used for AUTOVON. Both use access fees based upon *capability* rather than utilization. AUTOVON capability is composed of three factors.

[1]This objective was established and defined for DCA by the Joint Chiefs of Staff.

[2]These objectives normally refer to busy-hour traffic.

The first factor is directionality. Access lines can be conditioned to generate and/or accept calls; thus there are *two-way*, *one-way-in*, and *one-way-out* lines. The number and type of lines are selected by the subscriber agency with advice from DCA. One-way-out lines are priced as though they generate twice as many calls as a two-way line, and receive double weight in the billing process. One-way-in lines, however, pay no backbone cost because it is believed that they relieve network congestion.

The second factor of capability is precedence. A routine line which cannot pre-empt is assigned a relative weight of one. Priority lines which can pre-empt routine calls are given a relative weight of two. Immediate and flash lines have relative weights of three and four, respectively.

Directionality and precedence are used to compute *weighted* units and a two-way routine line is one weighted unit, a two-way priority line is two weighted units, an immediate line is three units and a two-way flash line is four units. A one-way-out flash line is eight weighted units. A further modification exists in some parts of the AUTOVON network where data transmission lines must be specifically conditioned; these lines receive double weight in the calculation of weighted units. Table 1 shows the number of weighted units assigned to each category of line.

Table 1. WEIGHTED UNITS AND LINE TYPES

| | Precedence | | | |
|---|---|---|---|---|
| Type of Service | Routine | Priority | Immediate | Flash |
| Phone/Data and Send Only (one-way-out) | 2 | 4 | 6 | 8 |
| Two-way | 1 | 2 | 3 | 4 |
| Receive only (one-way-in) | 0 | N/A | N/A | N/A |

The third factor of capability is area. For cost allocation purposes DCA recognizes four areas: CONUS, Pacific, Europe and Caribbean. In addition, there are the costs of reaching each of the other three from CONUS. Thus, in all there are seven cost pools to which all AUTOVON costs are assigned. Access lines are conditioned for a maximum calling area, so one AUTOVON line cannot necessarily reach any other access line. A CONUS line can call only CONUS subscribers; a Pacific line can only call Pacific subscribers; a CONUS-Pacific line can call both.

On the basis of area capability, DCA aggregates the number of weighted units sharing each cost pool. An access line in CONUS with capability to call Europe (or a line in Europe with a capability to call CONUS) shares the costs for CONUS, Europe and CONUS to Europe. A CONUS line with only CONUS capability shares only CONUS costs. An average cost per weighted unit is calculated for each of the cost pools. The charge for an access line is found by summing the applicable area and inter-area costs per weighted unit and multiplying the total by the number of weighted units assigned to that line.

Table 2 illustrates how the rates per weighted unit for each area and inter-area service component are computed. For example, consider a two-way access line having priority precedence and area plus capability for CONUS and Europe. The monthly charge *per weighted unit* for this line would be $253 for CONUS plus $303 for CONUS to Europe plus $35 for Europe--a total of $591. Since two-way priority lines count as two weighted units, the total charge for the line would be $1182. Other combinations are calculated in the same fashion. A global access line incurs all of the costs included in the seven pools.

AUTOVON charges must be established for subscribers two fiscal years in advance. For example, DCA must set charges for fiscal 1981 in fiscal 1979. Consequently, the costs per weighted unit must be calculated using projections of numbers

Table 2. AUTOVON BACKBONE RATE CALCULATION
($ in 000's, approximation of FY 1978 costs and connections)

| Costs by Geographic Area | Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | CONUS | CONUS-Europe | Europe | CONUS-Pacific | Pacific | CONUS-Caribbean | Caribbean | Total |
| 1. Service Observing | 202 | -- | -- | -- | -- | -- | -- | 202 |
| 2. Operators | 129 | -- | -- | -- | -- | -- | -- | 129 |
| 3. Directory | 36 | -- | 12 | -- | 12 | -- | 3 | 63 |
| 4. Leased Switches | 3,169 | -- | 52 | -- | 1,279 | -- | -- | 4,500 |
| 5. Trunks | 51,558 | 6,659 | 555 | 5,357 | 9,845 | 1,485 | -- | 75,459 |
| 6. O&M of Owned Switches | -- | -- | 678 | -- | 562 | -- | 57 | 1,297 |
| 7. Other Costs and Adjustments (Net) | 2,978 | 144 | 96 | 357 | 733 | 108 | 5 | 4,421 |
| Adjusted Cost Totals | $58,072 | $6,803 | $1,393 | $5,714 | $12,431 | $1,593 | $65 | $86,071 |

| Rate Base By Weighted Units | Weighted Units Per Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Maximum Call Area | CONUS | CONUS-Europe | Europe | CONUS-Pacific | Pacific | CONUS-Caribbean | Caribbean | Total Weighted Units |
| 1. Europe-Local | -- | -- | 840 | -- | -- | -- | -- | 840 |
| 2. Europe-Area | -- | --- | 16,344 | -- | -- | -- | -- | 16,344 |
| 3. Pacific-Local | -- | -- | -- | - | 324 | -- | -- | 324 |
| 4. Pacific-Area | -- | -- | -- | | 8,508 | -- | -- | 8,508 |
| 5. CONUS-Area | 189,600 | -- | -- | -- | -- | -- | -- | 189,600 |
| 6. CONUS-Europe | 9,384 | 9,384 | 9,384 | -- | -- | -- | -- | 9,384 |
| 7. CONUS-Pacific | 14,676 | -- | -- | 14,676 | 14,676 | -- | -- | 14,676 |
| 8. CONUS-Caribbean | 2,760 | -- | -- | -- | -- | 2,760 | 2,760 | 2,760 |
| 9. Global | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 |
| Total | 229,476 | 22,440 | 39,624 | 27,732 | 36,564 | 15,816 | 15,816 | 255,492 |
| Rate Per Weighted Unit = A/B ($ Rounded for Service Shown) | $253 | $303 | $35 | $206 | $340 | $101 | $4 | $1,242 (Global) |

Source: DCA.

Note: Canadian and STRAWHAT costs excluded for simplification.

of access lines obtained from the subscriber agencies. The amount of funds actually collected by DCA through access line charges in a given year will not equal the total payout from CSIF unless the agencies connect the number and type of access lines projected in the planning figures given to DCA. The projections are rarely completely accurate. For example, in FY 1976 billable weighted units fell short of planning estimates by almost 6 percent, resulting in about a 7 percent revenue shortage.

## D. EVALUATION OF THE CURRENT CHARGING SYSTEM

### 1. Equity and Access Line Costs

One of the main objectives of this paper is to analyze the potential effects on users of instituting a usage-sensitive charging system. Before we broach this question, however, we should like to examine the current rate structure in order to determine whether, in its present non-usage, sensitive form, it properly allocates costs to those people who, by virtue of their capability to make certain kinds of calls, place demands on AUTOVON's facilities. Although the access charges for AUTOVON are based on three characteristics--directionality, precedence and area coverage--none of these charges reflect the actual costs of the three characteristics. The monthly port fee charged by a common carrier for a line or a trunk, for example, is the same whether it is two-way or one-way; and the cost of providing pre-emption capability is nearly the same regardless of the level of precedence provided.

One way of evaluating whether or not the current system allocates the costs equitably is to determine whether agencies with the capability to use certain portions of AUTOVON are paying, on average, the costs of providing the services. The costs are presently allocated on the basis of weighted units. But the weighted units are themselves arbitrarily defined and

vary primarily as a function of the weighting system assigned to precedence; if different weights were assigned to different precedences, a different allocation of costs would occur.

For a subscriber, however, the relevant figure is not the charge per weighted unit that he pays but the fee per access line. A single access line has a fixed transmission capacity regardless of its other characteristics (although a high precedence line may be much more efficient than a low precedence line). The number of lines of different precedence that a subscriber needs is a function of the number of calls made and received. It is the charge per line that matters most to him. Likewise, the costs of the system are a function of the number of lines rather than the number of weighted units. For example, if all lines were assigned flash priority, the number of lines and total costs would be little changed but the number of weighted units would increase greatly.

## 2. Precedence and Distance

We can evaluate both the role of precedence and the equity of the current billing system by comparing the average *charge* per line for various area capabilities to the average *cost* per line of providing these capabilities. When we do this, we find that the distribution of precedence lines is vastly different for the various service categories and that the primary function of precedence, from an economic point of view, is to allocate costs that are more properly a function of distance.

There are three categories of area capability--area, area-plus and global--which, respectively, give subscriber access to one area (CONUS, Europe, Pacific, or Caribbean) or all areas. There are eight different rates associated with these capabilities. The monthly billing charges *per weighted unit* for the eight service areas are given in Table 3. Table 3 also shows the average number of weighted units *per line* and the average charge *per line* for each service area.

Table 3. CHARGES FOR SERVICE -- PER WEIGHTED UNIT AND PER LINE
(Based on Projections for FY 1978)
(Dollars per Month)

| Type of Service | Charge Per Weighted Unit[a] | Average Weighted Units per Line[b] | Average Charge per Line[c] |
|---|---|---|---|
| Area | | | |
| CONUS | $ 253 | 1.13 | $ 286 |
| Europe | 35 | 1.75 | 61 |
| Pacific | 340 | 1.85 | 629 |
| Caribbean | 4 | -- | -- |
| Area Plus | | | |
| CONUS-Europe | 591 | 3.30 | 1950 |
| CONUS-Pacific | 799 | 3.46 | 2765 |
| CONUS-Caribbean | 358 | 2.67 | 956 |
| Global | | | |
| All | 1242 | 3.58 | 4448 |

[a]The charge per weighted unit is based on DCA data for FY 1978 projections and billing. See Table 2.

[b]Calculated using the data on "weighted units per area" contained in Table 1, October 1977 draft of IDA AUTOVON Paper. The numbers in the table were divided by 12 to get actual number of weighted units. The number of lines is the number in place on April 30, 1977.

[c]The average charge per line is calculated as the average number of weighted units per line times the charge per weighted unit.

In comparing the first and third columns of the table, it is evident that the relationships among the charges *per weighted unit* for area, area plus and global are much different than those among the average charges *per line*. For example, although the charge *per weighted unit* of a line with global

capacity is approximately 5 times that *per weighted unit* for a CONUS only line, the average charge *per line* with global capacity is over 15 times the average charge *per line* with CONUS capacity. It is precedence that accounts for these large differences in the ratios of charges per weighted unit and the ratios of charges per line.

A weighted unit is the equivalent of a routine two-way line. The high average charges per line for area plus and global are due to the fact that 97 percent of the area plus lines and 99 percent of the global lines are of precedence above routine, while 79 percent of the area plus lines and 91 percent of the global lines are of precedence above priority.[1] On the other hand, only 9 percent of the CONUS area lines are of precedence above priority and 13 percent above routine. As a result, the average charge per line is much lower than for the overseas lines. The average charge for CONUS lines is drawn down still further by the fact that 30 percent of them are in-only and have a zero backbone charge.

The impact of these differences in the distribution of precedences is illustrated by the figures in column two of the table which reflect the average level of precedence for the different service categories. The charge per global line is 3.58 times the charge per weighted unit, for example, while the charge per CONUS line is only 1.13 times the charge per weighted unit. In reality the charges for precedence are something of a facade. The volume of overseas traffic relative to trunk capacity is so high that a line below immediate or flash precedence would be nearly worthless for placing calls. If a routine or priority call did get through, the expected length of conversation would be very short. The capacity of the overseas trunks is effectively exhausted (perhaps more than

[1]There are 676 area plus lines and 304 global lines.

exhausted depending upon the grade of service one uses as standard) by the current number of overseas access lines. *Thus, in peacetime, the allocation of precedence lines becomes essentially a means of allocating overseas access and the precedence charge becomes a fee for overseas calls.* Our earlier citations of the percentage of overseas lines with high precedence compared to CONUS lines with precedence substantiates this conclusion.

If the precedence charges are fundamentally a means of allocating the costs of overseas service, we must next inquire into how efficiently they do the job. We can answer this question in a relatively unsophisticated but simple fashion by comparing the average cost per line of providing the various types of service to the average revenue per line received from subscribers. In doing so, we can determine how closely the current pricing policies conform to what might be called an average cost pricing policy, with costs segregated according to geographic service areas.

We already have the average revenue per line for these from the last categories of Table 3. To calculate the average cost per line of providing each kind of service, we can use the same methodology that DCA uses in calculating the cost per weighted unit. But instead of using weighted units we can allocate the service cost pools to the lines that have access to the services. The figures for the average costs per line along with the number of lines are shown in Table 4.[1] Thus, the average cost per line for the facilities that serve CONUS and Europe is $1,048. The average cost per line for service facilities within Europe is $85.[2] The average cost for a CONUS-Europe line would be the sum of these, or $1,456.

---

[1]We should reiterate that these costs are not the costs of various area capabilities but the cost per line of providing the facilities in area and the facilities that link areas.

[2]The Europe area service is cheap partly because all the switches are government owned and no operating costs are attributed to them. On the other hand, the O and OM costs of these switches is a large proportion of the total.

Table 4. AVERAGE COSTS PER LINE OF VARIOUS GEOGRAPHIC CATEGORIES OF SERVICE
(Thousands of Dollars)

| | CONUS | CONUS-Europe | Europe | CONUS-Pacific | Pacific | CONUS-Caribbean | Caribbean | Total |
|---|---|---|---|---|---|---|---|---|
| Cost by Geographic Area | $58,072 | $6,803 | $1,393 | $5,714 | $12,431 | $1,593 | $65 | $86,071 |
| Area | Lines per Area | | | | | | | |
| Europe Local | -- | -- | 76 | -- | -- | -- | -- | |
| Europe Area | -- | -- | 743 | -- | -- | -- | -- | |
| Pacific Local | -- | -- | -- | -- | 17 | -- | -- | |
| Pacific Area | -- | -- | -- | -- | 380 | -- | -- | |
| CONUS Area | 14,013 | -- | -- | -- | -- | -- | -- | |
| CONUS-Europe | 237 | 237 | 237 | -- | -- | -- | -- | |
| CONUS-Pacific | 353 | -- | -- | 353 | 353 | -- | -- | |
| CONUS-Caribbean | 86 | -- | -- | -- | -- | 86 | 86 | |
| Global | 304 | 304 | 304 | 304 | 304 | 304 | 304 | |
| TOTAL | 14,933 | 541 | 1,360 | 657 | 1,054 | 390 | 390 | |
| Average Cost Per Line/Month | $323 | $1,048 | $85 | $725 | $983 | $340 | $14 | |

Source: DCA.

In Table 5 we show the average cost per line of providing service with different area capabilities along with the current charges for these services. It is readily apparent that on average the subscribers to area-only service do not pay their full share of the costs of that service. CONUS subscribers pay 89 percent of their costs, nearly a full share, but Pacific subscribers pay only 64 percent. Transoceanic subscribers, on the other hand, are overcharged. CONUS-Europe and CONUS-Pacific subscribers pay approximately one-third more than the cost while global subscribers pay 25 percent more. These percentage differences apply as well to the aggregate cost and revenue figures which are also shown in Table 5.

*If one were to judge the present billing structure by the criterion that it should, on average, allocate costs to those who cause them, one could conclude that it fails by a considerable margin in achieving this goal. As a group, area plus and global subscribers are subsidizing those with only area capability.* In a sense, the current situation corresponds to what might exist if overseas trunking capacity was fixed and allocated to high bidders. In that case, there would be no reason for the prices bid to correspond to the costs. With the additional constraint that there would be zero profits, the excess funds from overseas subscribers would have to be used to subsidize other services. There is no such market for the overseas services, however, and the rights to them are allocated primarily on the basis of the DoD's judgment as to who needs them. As a result, equity considerations would call for those who use a particular service to pay the cost of providing it. When we are dealing only with average costs and a billing system based on access and precedence, this goal can be accomplished only on the average. Under this criterion, area subscribers would pay more than they do now while overseas subscribers would pay less.

Table 5. AVERAGE COST AND AVERAGE INCOME BY TYPE OF SERVICE

| | Average Cost and Revenue Per Line (Dollars per Month) | | | Total Cost and Revenue (Thousands of Dollars per Month) | |
|---|---|---|---|---|---|
| Type of Service | Average Cost | Average Charge[a] | Number of Lines | Cost | Revenue |
| AREA | | | | | |
| CONUS | $ 323 | $ 286 | 14,013 | $ 4,523 | $ 4,008 |
| Europe | 85 | 61 | 819 | 70 | 50 |
| Pacific | 983 | 629 | 397 | 390 | 250 |
| Caribbean | 14 | 4 | NA | -- | -- |
| AREA PLUS | | | | | |
| CONUS-Europe | 1,456 | 1,950 | 237 | 345 | 462 |
| CONUS-Pacific | 2,031 | 2,765 | 353 | 717 | 976 |
| CONUS-Caribbean | 677 | 956 | 86 | 58 | 82 |
| GLOBAL | | | | | |
| All | 3,518 | 4,446 | 304 | 1,069 | 1,352 |
| Totals (Monthly) | | | | 7,173 | 7,179 |
| Totals (Yearly) | | | | 86,071 | 86,153 |

[a]See Table 1. These are averages based on the present system of allocating costs. The average charge is based on the number of lines in place on 30 April 1977.

An allocation of costs that is on average more equitable could be achieved in a number of ways by modifying the current billing procedures. One way in which this could be accomplished is shown in Table 6. The figures in Table 6 are derived from Tables 3 and 5. All that we have done is take the average cost per line for each type of service and divide it by the average number of weighted units per line to arrive at a charge per weighted unit for each type of service. As expected, the weighted unit charges rise for area service and fall for overseas service.

If the subscribers' selection of precedence and type of service did not change because of the alterations in billing, their charges would result in each group of users paying the costs of its own service, a more equitable situation than at present. If subscribers did adjust, new prices could eventually be found to achieve equity.

Table 6. CHARGES PER WEIGHTED UNIT THAT RESULT IN USERS PAYING AVERAGE COST OF SERVICE
(Dollars per Month)

| Type of Service | Average Cost of Service[a] | Average Weighted Unit per Line | New Charge per Weighted Unit[b] | Present Charge per Weighted Unit[c] |
|---|---|---|---|---|
| Area | | | | |
| CONUS | $ 323 | 1.13 | $286 | $ 253 |
| Europe | 85 | 1.75 | 49 | 35 |
| Pacific | 983 | 1.85 | 531 | 340 |
| Caribbean | 14 | | -- | 4 |
| Area Plus | | | | |
| CONUS-Europe | 1456 | 3.30 | 441 | 591 |
| CONUS-Pacific | 2031 | 3.46 | 587 | 799 |
| CONUS-Caribbean | 677 | 3.67 | 254 | 358 |
| Global | | | | |
| All | 3518 | 3.58 | 983 | 1242 |

[a]See Table 3.

[b]These are calculated by dividing the average cost per line by the average weighted units per line.

[c]See Table 1.

The new charges per weighted unit shown in Table 6 are based on the assumption that the current precedence multipliers of 1, 2, 3 and 4 are unchanged. Since the precedence charges are in large measure surrogates for distance charges, they (in addition to or instead of the weighted units) could also be manipulated in such a way as to reallocate costs so that each group of users pays for the share of the facilities it uses. This goal might, in fact, be used as a rationale for setting the precedence multipliers since their current values appear to be quite arbitrary. Selection of appropriate multipliers that would satisfy this goal would require some work to develop a computer model of costs, access lines and precedence choice but would not be an impossible task. The costs of precedence, both real costs and the social costs imposed on those pre-empted, could also be taken into account. We shall discuss these costs more fully later when we consider precedence within a usage charge system.

### 3. Directionality--One-Way Lines

In estimating the average cost per line to which the average charge should be equated, we accepted one aspect of the current billing procedure that in itself requires examination--the practice of assigning a zero weighted unit to in-only lines. DCA does not presently charge for access lines which permit only incoming calls. The argument in favor of this policy is that one-way-in lines are capable only of taking calls off the network, thus reducing network congestion and increasing total capacity without adding trunks.

There are flaws in the assumption that adding a one-way-in line increases *only* the capacity to take calls off the system; depending upon the distribution of incoming and outgoing calls, an additional one-way-in line can increase *out* capacity nearly as much as it does *in* capacity. Suppose a user has a single

two-way line which he finds insufficient for his requirements, and that incoming and outgoing calls are equally probable. If he adds a new one-way-in line and assures that all incoming calls are directed first to it and go to the two-way line only if the in-line is busy, the two-way line will have considerably greater capacity to handle outgoing calls. Since we assumed that it was excess demand that prompted the installation of the new line, there will now be more outgoing as well as more incoming calls. Once users (both those calling in and those calling out) learn that the waiting time is less and that the probability of successfully completing a call is greater, they will respond by placing more calls. Thus, a one-way-in line will not simply take calls off the system and reduce congestion on the trunks; it will also permit more calls to be placed on the two-way lines that it frees up, and generate more traffic.

Users are well aware of the effect of one-way-in lines on outgoing capacity and have taken advantage of it to reduce their backbone charges in ways already noted by the General Accounting Office and others. Rather than adding new in-lines to an otherwise optimal mix of one-way-in, two-way and one-way-out lines, some subscribers have simply replaced one-way-out and two-way lines with one-way-in lines. As a result, they reduce their costs without increasing their capacity.[1] When they acquire a one-way-in line, users must pay the connectivity and access line mileage fees. These comprise nearly half the total cost of an access line or about $2,600 per year on average. Thus, one-way-in lines are not a free good even with a zero backbone charge.[2] They are, nevertheless, much cheaper than a two-way line. The

[1]The rationale for this sort of decision can be illustrated very easily. Suppose a location has an equal number of incoming and outgoing calls. It can lease two two-way or a one-way-in and one-way-out line at a cost of 2, it can lease a two-way and a one-way-out line at a cost of 1. Ignoring the stochastic nature of telephone calls and holding times, it is evident that the latter is the cheapest combination that can satisfy its requirements.

[2]See Chapter III for cost figures.

incentives to replace other lines are large. The incentive to add new ones is small.

Thus, the backbone charge for one-way-in lines should certainly not be zero; nor should it be the same as for two-way lines. A proper weighting system for the lines should recognize the interaction between the types of lines in the mix purchased by the subscriber. Detailed analysis is needed in order to provide a defensible methodology for pricing lines in the absence of usage charges. In Appendix A we briefly outline some steps that may help provide a solution to the problem.

There is another characteristic of in-only lines that can lead to a misallocation of costs. The lines are much more advantageous for a large facility than for a small one. If a facility has only one phone, it clearly must be two-way. The larger the number of lines, however, the greater proportion of in-only lines that can efficiently be introduced. Thus, a zero backbone charge for in-only tends to subsidize large facilities relative to small ones.

Charging for in-only access lines would improve the allocation of total costs as well as correct the distortions caused by pricing in-only lines at zero. The majority of the in-only lines are area lines in CONUS (4299). There are a few in Europe (105) and the Pacific (124). If the CONUS lines were priced the same as two-way lines and assigned a value of one weighted unit, their inclusion in the number of weighted units used to price CONUS weighted units would result in a lower monthly charge, thus reducing the cost of any individual line (including overseas with high precedence) having access to CONUS. At the same time, assigning a weighted unit value of one to in-only lines would raise the average number of weighted units per line in CONUS, thus increasing the *average* per line. The same result would hold for Europe and Pacific area lines. Table 7 shows the new allocation of costs per weighted unit when in-only lines are

Table 7. HYPOTHETICAL AUTOVON BACKBONE RATE CALCULATION WITH IN-ONLY LINES COUNTED AS ROUTINE TWO-WAY

| | AREA | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CONUS | CONUS-Europe | Europe | CONUS-Pacific | Pacific | CONUS-Caribbean | Caribbean | Total |
| Annual Costs by Geographic Area (Thousands of Dollars) | $58,072 | $ 6,803 | $1,393 | $12,431 | | $1,593 | $65 | $86,071 |
| Weighted Units Per Area (Including In-Only Lines) | | | | | | | | |
| Maximum Call Area | | | | | | | | |
| Europe-Local | -- | -- | 840 | -- | -- | -- | -- | 840 |
| Europe-Area | -- | -- | 17,604 | -- | -- | -- | -- | 17,604 |
| Pacific-Local | -- | -- | -- | -- | 324 | -- | -- | 324 |
| Pacific Area | -- | -- | -- | -- | 9,996 | -- | -- | 9,996 |
| CONUS-Area | 241,752 | -- | -- | -- | -- | -- | -- | 241,752 |
| CONUS-Europe | 9,384 | 9,384 | 9,384 | -- | -- | -- | -- | 9,384 |
| CONUS-Pacific | 14,676 | -- | -- | 14,676 | 14,676 | -- | -- | 14,676 |
| CONUS-Caribbean | 2,760 | -- | -- | -- | -- | 2,760 | 2,760 | 2,760 |
| Global | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 | 13,056 |
| Total | 281,628 | 22,440 | 40,884 | 27,732 | 38,052 | 15,816 | 15,816 | 310,392 |
| Monthly Rate Per Weighted Unit = A/B | 206 | 303 | 34 | 206 | 327 | 101 | 4 | 1,181 (Global) |

Canadian anc STRAWHAT costs excluded for simplification.

counted the same as two-way lines. The data are the same as that in Table 2 except for the inclusion of in-only lines in calculating the number of weighted units.

The charge per weighted unit in CONUS falls from $253 to $206. The cost per weighted unit in Europe falls from $35 to $34 and that for the Pacific falls from $340 to $327. These area costs enter into the calculation of charges for all overseas services. Thus, the charges for different services are nearly all affected. Table 8 compares the potential charges when a unit weight is assigned to the in-only lines to the current charges where the in-only receives a zero weight. The charge per weighted unit falls in all cases.[1] The *average* charge per line, however, rises for area service (in CONUS, for example, from $286 to $297) because the number of weighted units per line increases. The average charge per line for overseas lines falls in all cases but still lies above the average cost per line.

Having described the system as it currently functions and indicated some ways in which the allocation of costs could be improved without fundamentally changing the billing system, we can now consider more thoroughly the principles of usage sensitive pricing and how its introduction might be expected to affect the behavior of agencies and individuals.

---

[1]These calculations assume the total number of lines would not change. It is possible there would be some reduction in the total number of lines if in-only were priced the same as two-way. The most likely outcome would find in-only being replaced by two-way.

Table 8. CHARGES FOR SERVICE--PER WEIGHTED UNIT AND PER LINE--WITH AND WITHOUT IN-ONLY LINES (DOLLARS PER MONTH)

| Type of Service | Charge Per Weighted Unit | | Average Weighted Units per Line | | Average Charge Per Line | | Average Cost of Service |
|---|---|---|---|---|---|---|---|
| | Without In-Only[a] | With In-Only | Without In-Only | With In-Only | Without In-Only | With In-Only | |
| AREA | | | | | | | |
| CONUS | $ 253 | $ 206 | 1.13 | 1.44 | $ 286 | $ 297 | $ 323 |
| Europe | 35 | 34 | 1.75 | 1.88 | 61 | 64 | 85 |
| Pacific | 340 | 327 | 1.85 | 2.17 | 629 | 710 | 983 |
| Caribbean | 4 | 4 | | | | | 14 |
| AREA PLUS | | | | | | | |
| CONUS-Europe | 591 | 543 | 3.30 | 3.30 | 1,950 | 1,792 | 1,456 |
| CONUS-Pacific | 799 | 739 | 3.46 | 3.46 | 2,765 | 2,557 | 2,031 |
| CONUS-Caribbean | 358 | 311 | 2.67 | 2.67 | 956 | 830 | 677 |
| GLOBAL | | | | | | | |
| All | 1,242 | 1,181 | 3.58 | 3.58 | 4,448 | 4,228 | 3,518 |

[a]See Table 3.

# Chapter II

# USAGE-SENSITIVE COST ALLOCATION: PRINCIPLES AND PROBLEMS

## A. INTRODUCTION

The previous section provided a relatively complete description of the AUTOVON system as it presently functions and identified several aspects of AUTOVON that are relevant to the problem of allocating costs. These include the following:

- Although the system was initiated and designed to satisfy defense contingency needs, except for the overseas system those needs do not adequately explain its present configuration and capacity. In CONUS that capacity is due to the growing volume of routine communications.
- The present method of allocating capacity among users is by precedence and by congestion. There are differences between overseas calls and CONUS calls. The average level of precedence is much higher for an overseas call than within CONUS. At the same time, the overseas congestion level is much worse. The access fees for precedence thus come to correspond more closely to a charge for overseas capability than for improved service. Importantly, this method of charging is not usage-sensitive in the strict sense of the term.
- The value of a change in pricing and billing procedures should be judged by its effects on direct usage and on the number and type of access lines selected. Given the existing trunk capacity, congestion can be reduced either by increasing the number of access lines or by shortening and reducing the number of calls.
- At present the system does not produce sufficient information to permit billing for usage. Collecting the information would require the installation of Automatic Message Accounting (AMA) equipment at some expense. In evaluating whether AMA would be justified, one should examine not only the cost and value of total coverage by AMA but partial coverage as well.

In this Chapter we review alternative methods of allocating the costs assciated with AUTOVON. In particular we discuss and evaluate the employment of usage-sensitive allocative techniques. In the following chapter we present some methodologies for making the appropriate calculations if usage-sensitive pricing were to be adopted and indicate some estimated magnitudes of various costs. Since there is a limited amount of data available, in some cases these costs are hypothetical.

## B. MARGINAL COST PRICING AND USAGE SENSITIVITY

The allocative problems posed by AUTOVON share many of the characteristics of a broad set of situations that have been extensively studied by economists. In such circumstances there exists a facility of fixed capacity. This capacity must be allocated among potential users. In addition, rules must be developed to determine when and under what circumstances that capacity should be enlarged. The solution to the problem involves devising a set of charges that will lead to the facility being utilized so as to maximize its productivity, and thus minimize the costs of providing services.

The existence of AUTOVON is justified by the fact that communication needs in the event of a national emergency require a dedicated telephone network. In the absence of an emergency these facilities have unused and economically useful capacity. An appropriate question is: How can this capacity be best allocated among alternative users? In addition, given that the emergency capacity is inadequate for peacetime demands, how should it be expanded upon or integrated with other facilities in order to maximize the economic value of the whole?

The general set of economic principles which guide efficient allocation is marginal cost pricing. A strict application of marginal cost pricing would require that the price of each service provided by the system be equal to the actual cost of the

resources used in producing the last unit of that service. A corollary proposition is that, if prices are different from marginal costs, inefficiency will result.

If, as is the case with AUTOVON, there are some fixed costs of operation and a requirement that all costs be covered by revenues generated, the marginal cost principle enunciated above must be modified. The cost per unit of service should still be the marginal cost, but the fixed costs should be recovered by an entry fee that is independent of use. Thus the pricing system would have two components: a fixed charge for the right to use the system and a charge that varies with usage and with the indices of usage which are related to costs (e.g., number and duration of calls, distance called, time of day). Generally, the application of marginal cost pricing principles is referred to as usage-sensitive pricing.

There are circumstances in which usage-sensitive charges are inconsistent with overall efficiency. These are situations in which the costs of charging or metering exceed the value of any added efficiency gained thereby. For example, fares may not vary according to distance or urban public transit systems because the costs of measuring and charging for differences in distance traveled may exceed any revenue or welfare gains that result. Tnus, in attempting to assess the desirability of instituting a usage-sensitive cost allocation system in a particular situation, we must take into account not only the potential efficiency to be gained by usage-sensitive pricing, but the costs of measuring and billing for usage.

## C. USAGE SENSITIVITY AND ALLOCATIVE EFFICIENCY IN TELEPHONIC COMMUNICATION

A wide variety of research has been undertaken to design usage-sensitive pricing schemes and assess their efficiency in

private sector telephone communications.[1] The virtually unanimous conclusion of this research is that usage sensitivity does produce net economic benefits in the private sector. Private telephone systems have been moving rapidly to incorporate as fully as possible the essential features of such systems into their billing practices. While there are significant differences between the purposes and techniques of AUTOVON and private telephone communications, such findings suggest that the applicability to AUTOVON of usage-sensitive pricing should be examined.

To understand the potential efficiencies to be gained by usage-sensitive charging, we must first summarize the nature of the relationship between a pricing system and allocative efficiency. An allocative mechanism must provide information useful in achieving at least two objectives: the determination of the capacity of the communication system and the allocation of that capacity among alternative uses. The first of these objectives is achieved by a response on the supply side, the second involves forcing users to make choices. The pricing system merely supplies information to suppliers and demanders which enables them to make these decisions.

The process of reaching optimal capacity requires that the system be expanded only if the value of additional calls be equal to the cost of expansion. Optimal allocation of a given capacity requires that, if only x calls can be made, the calls actually made be the x most valuable ones.

Marginal cost pricing, accompanied by appropriate supplier response, simultaneously achieves both of these objectives. The existence of excess demand for available services serves as a signal to expand capacity. The fact that the service is priced at the cost of providing such expansion assures its financing.

---

[1]See in particular the bibliography found in Bridger Mitchell, *Optimal Pricing of Local Telephone Service*, RAND Corporation, R-1962-MF, November 1976.

The distribution of calls among users can also be presumed to be efficient because of cost-minimizing behavior by those users. Anyone who values the service at less than its cost will refrain from using it.

These then are the ultimate sources of the benefits from usage-sensitive pricing. In appraising the role of such pricing to improve the efficiency with which AUTOVON capacity is determined and allocated, we must keep in mind the following questions:

- To what extent do the procedures employed by AUTOVON approximate the results of an efficient system; i.e., what are the sources and magnitude of the inefficiencies associated with current AUTOVON procedures?
- To what degree are the people who select access lines and those who make calls actually sensitive to the prices they pay for calls and lines?
- What would be the likely response if usage sensitivity charges were instituted for AUTOVON?
- What are the costs of converting the system to usage sensitivity?

In short, what are the benefits and costs associated with usage-sensitive pricing? In attempting to answer this question, it is important to recognize that we are not necessarily dealing with an all-or-nothing situation. There may be segments of the AUTOVON system where the benefits of usage-sensitive pricing outweigh the costs of the limited amount of AMA equipment that would be required to obtain the necessary data even though an overall adoption of usage-sensitive pricing might not be warranted.

## D. EXISTING AUTOVON PROCEDURES: SOURCES OF INEFFICIENCY

In discussing how capacity is determined, it is necessary to differentiate between CONUS service and overseas service. The size of the overseas network is set by contingency requirements. Demands on the network in peacetime greatly exceed this capacity and congestion is high. No attempt is made, however,

to relieve congestion by increasing the number of overseas trunks or otherwise expanding transmission capacity.

There presumably is a basic system in CONUS that also corresponds to contingency requirements, but the actual CONUS capacity substantially exceeds these requirements. Capacity in CONUS is responsive to congestion since the CONUS network is meant to be used for normal peacetime business. When the backbone grade of service in CONUS differs from the target of P.13 for routine calls, trunks are added or subtracted. Thus, in evaluating how usage-sensitive pricing might aid in achieving the two objectives of optimal capacity and appropriate allocation among users, we must keep in mind that we may draw different conclusions and recommend different policies for the two systems.

For example, as long as the overseas network size is determined exclusively by contingency requirements, no amount of information provided by usage-sensitive pricing and excess demand will have any effect on capacity. User behavior may be affected by pricing changes, but the supply response will be zero. In CONUS, on the other hand, if excess demand reduces the backbone grade of service below P.13, the number of trunks is generally increased. Response to the pricing structure, therefore, can affect both the capacity decisions and the allocation of capacity among users.

The allocation of AUTOVON capacity in both CONUS and overseas is done presently through precedence and congestion. The higher the precedence of an access line, the more likely a call placed on that line will reach its destination. At the lowest level of precedence, congestion determines which calls are completed. Effectively this means that in CONUS, routine calls are completed on a first come, first serve basis. Those whose calls are not completed and who are not authorized a higher precedence level must simply attempt to place the call again or forego the opportunity. Of the individuals so blocked, those

who can persist and are willing to make the most attempts are the most likely ultimately to get through. The same situation exists with overseas calls except that congestion is much worse and any call of precedence below immediate has a very low probability of success.

As we noted in Chapter 1, these rules result in rather imperfect correlation between the average costs of providing service and the charges imposed. This is because much of the cost of overseas access is really collected through the precedence charges. Globally, the precedence charges serve primarily to allocate the costs of overseas service to those who use it.

Within each service area, however, the precedence system helps assure that higher value calls receive better service than low value ones. The precedence system reflects two considerations. One is the importance or urgency of the mission of the customer in his contingency role. Thus, the differing charges measure, albeit imperfectly, the relative importance of each activity in causing the system to exist at all, at least overseas. The other consideration is the ability to impose costs on others or, in its positive aspect, to secure better service, which pre-emption accords the high precedence user. There is no fixed relationship between grade of service and cost; however, in fact, those who pay most relative to cost--the overseas subscribers--receive less in the way of quality or service than those who pay less relative to costs--the area subscribers.

What is absent in current AUTOVON billing procedures is usage sensitivity in the strict sense. The incremental charge for making any additional call is zero. This, in turn, means that congestion performs certain allocative functions normally left to the price system. The price which equates supply and demand is a congestion price measured primarily by the time costs of the related delays and interruptions.

Congestion is clearly capable of allocating capacity but it does so at considerable cost in efficiency. Chief among the problems are:

- It provides little assurance that the system will be of optimal capacity. Because no explicit charge is associated with the service, it is difficult to determine if the users of the service value it at more or less than it costs. That is, the absence of charges means that the data necessary to judge the appropriate level of output are not generated by the allocational mechanism itself.
- Whatever the capacity to be allocated, congestion is unlikely to result in the distribution of that capacity to its highest priority uses. Calls are free so a caller need not compare the value of his call to its cost.
- Congestion involves substantial costs. Individuals who are unable to reach a destination and who may have to place the call again have used time that could otherwise be devoted to alternative endeavors. If a market clearing price system were used in conjunction with a higher grade of service, this time cost would not be incurred.
- The use of waiting time and congestion as an allocation device may significantly increase congestion costs. The absence of accountability implicit in a non-price rationing scheme can easily lead to abuses of the system and consequent discipline problems. Such abuse increases congestion and the costs for authorized users.

It is worthwhile to note several dimensions of the costs discussed above and the inherent implications for subsequent analysis. First, several components of these costs are reflective of "external effects;" that is, the wasteful consequences of one individual's behavior are borne by another. For example, a low priority call from one unit prevents the completion of a more important call from another.

A second relevant aspect is that the cost components listed above are not explicit in the sense that they do not appear on any accounting report and therefore are not attributed to a particular cause. This also means that the magnitude of these

costs and the inefficiencies they reflect are difficult to measure. Nonetheless these costs are real; they should be added to the explicit dollar cost of AUTOVON to determine the total cost. An ideal allocative system would be one in which these total costs are minimized.

Implicit in the use of congestion as an allocative procedure is the degradation of the quality of service from what it could otherwise be. As we shall see, this is not necessarily a "bad" thing; for some purposes a lower quality of service can be more cost effective than one of higher quality and price. It does mean, however, that when comparing AUTOVON services with those that could be provided under a usage-sensitive program or with those provided commercially, such qualitative differences must be kept in mind.

Finally, we should point out that if the capacity of the two systems, CONUS and overseas, are to continue to be determined as they are, with overseas fixed and independent of excess demand and CONUS hovering around a P.13 grade of service, adoption of usage-sensitive pricing will not eliminate congestion. In CONUS the level of congestion is the decision rule. If a new pricing scheme reduces traffic, some capacity would presumably be eliminated. Therefore, the value of usage-sensitive pricing in CONUS cannot be judged by its effects on congestion. Rather, it must be evaluated in terms of whether or not it will reduce costs and better allocate calls for the given congestion level of P.13.[1] For the overseas network, on the other hand, reduced traffic would mean reduced congestion.

Optimally, of course, we would like to be able to minimize the total costs--the equipment charges plus the congestion costs. Part of the solution would be an optimal GOS, perhaps something

[1]This is not meant to preclude the possibility that DCA may wish to improve the target grade of service rather than reduce costs.

quite different from P.13 in CONUS. Unless we are able to measure the congestion costs, however, achieving such a minimization of costs would not be possible. A feasible alternative to fixing the GOS at P.13 would be to fix the dollar costs, perhaps at the present level, and then apply usage-sensitive pricing. If congestion and its associated costs were then reduced, this reduction would be a measure of the value of usage-sensitive pricing. On overseas lines we would need to make exactly this kind of evaluation. The capacity is fixed. Therefore, usage-sensitive pricing must be judged on whether or not it results in *reduced* congestion.

It may be that usage-sensitive pricing is an essential element of a comprehensive communications system. If DCA ever wishes to consider integrating AUTOVON with FTS and commercial services, both DCA and users must have a means for comparing marginal as well as total costs of various services. This implies usage-sensitive pricing would be required.

## E. INSTITUTIONAL ADAPTATIONS

Before we discuss alternatives to the present system of allocating AUTOVON backbone costs and potential ways of at least qualitatively estimating the costs and benefits which may result, it is worthwhile to discuss how the current policies attempt to deal with the misallocations that might stem from incorrect pricing. These policies appear to result in AUTOVON more nearly approximating an efficient configuration and, as a result, reduce the potential benefits of "proper" usage-sensitive charges.

The basic inefficiencies that can derive from an inappropriate allocative system are manifested in either (a) incorrect capacity, (b) incorrect distribution of that capacity among users, or (c) unnecessary costs (e.g., congestion). Existing AUTOVON procedures include factors which affect beneficially the first two items.

As we have observed, economic efficiency requires that an incremental unit of a service be priced at the cost of providing it. If a service has positive cost but a price of zero and all demand is being satisfied, too much of the service is being provided. Capacity is excessive. In AUTOVON the price of additional units of service is zero but not all demand is satisfied. Capacity is limited both in CONUS and overseas. Thus, one cannot say whether capacity is excessive or not. Congestion substitutes for price in allocating that capacity.

The principles relating demand, prices, capacity and congestion cost can be illustrated with some simple diagrams. In Figure 1 we show the notional demand for calls, the cost (or supply) schedule for providing these calls, and the realized demand schedule that results when congestion is present.[1] The *notional demand* is $D_N$. This is the demand for completed calls at each level of price per call if there were no congestion. $Q_0$ is the capacity that would be required to satisfy this demand when calls are priced at zero. The actual cost per call is MC. If a charge of MC per call were levied and capacity were free to adjust, both capacity and demand would end up at $Q_2$ and this system would operate efficiently.

$Q_1$ is a capacity level that might result either from choosing an arbitrary grade of service (as in CONUS) or from simply fixing the capacity according to a particular rule (as with overseas service). With capacity at $Q_1$, excess demand at a zero price is equal to $P_0 - Q_1$. If all calls had an equal probability of getting through, the resulting *realized demand curve* would be $D_R$ which lies inside $D_N$. The equal probability assumption defines the location of the line $D_R$ relative to $D_N$. The same

[1]We use the term demand somewhat loosely here. It is not clear, in view of the uncertainties in the outcome of any year's Defense budgeting process, exactly what a demand schedule means. We shall assume the budgets accurately reflect the value of the goods and services for which they are to be spent, however.

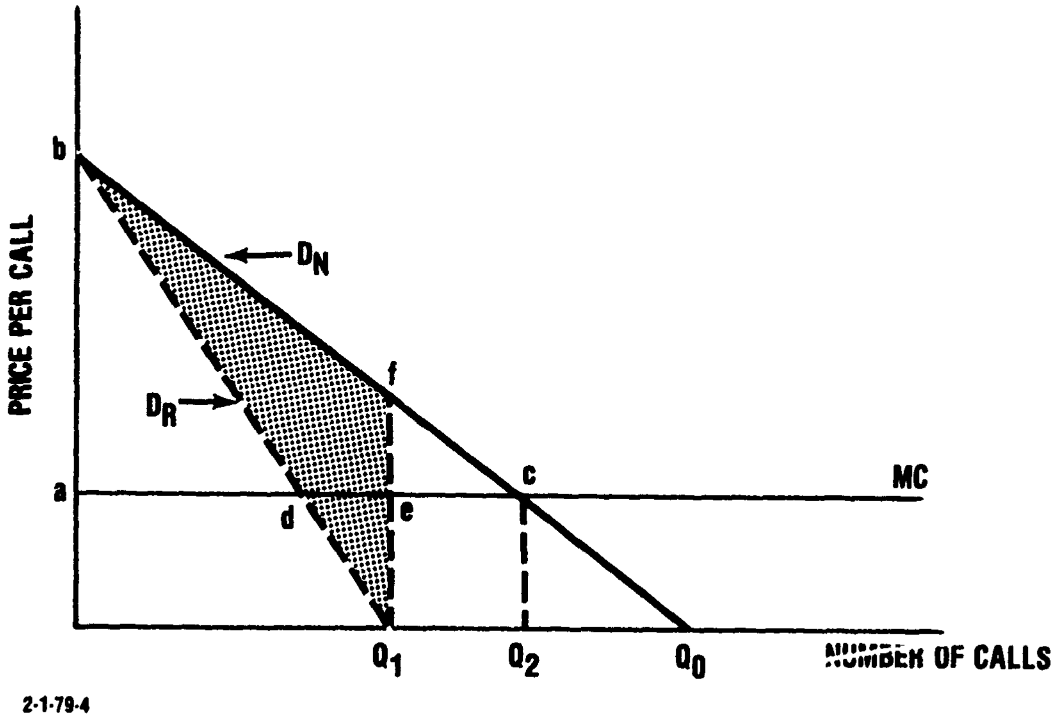



Figure 1. NOTIONAL AND ACTUAL DEMAND FOR TELEPHONE SERVICE

fraction of calls valued at any price could be expected to be successfully completed.

The cost of congestion, independent of any redialing costs, would be the shaded area in Figure 1, $bfQ_1$. This area would be the sum of the loss of consumers' surplus plus the deadweight loss involved in providing a service whose cost is MC to some people who value it at less than MC. The costs shown in Figure 1 are only the costs of not being able to successfully complete calls. If additional costs are incurred because of repeated attempts, these redialing costs must be added.

The location of the realized demand curve, $D_e$ in Figure 1, can be shifted both by policy choices and by the behavior of callers. The policy that will affect the realized demand curve is the presence of pre-emptive capability. If the right to pre-emption reflects the value of calls made, the high valued calls will always get through while the lower valued calls will suffer

greater than average congestion.[1] The result might be similar to what is shown in Figure 2.

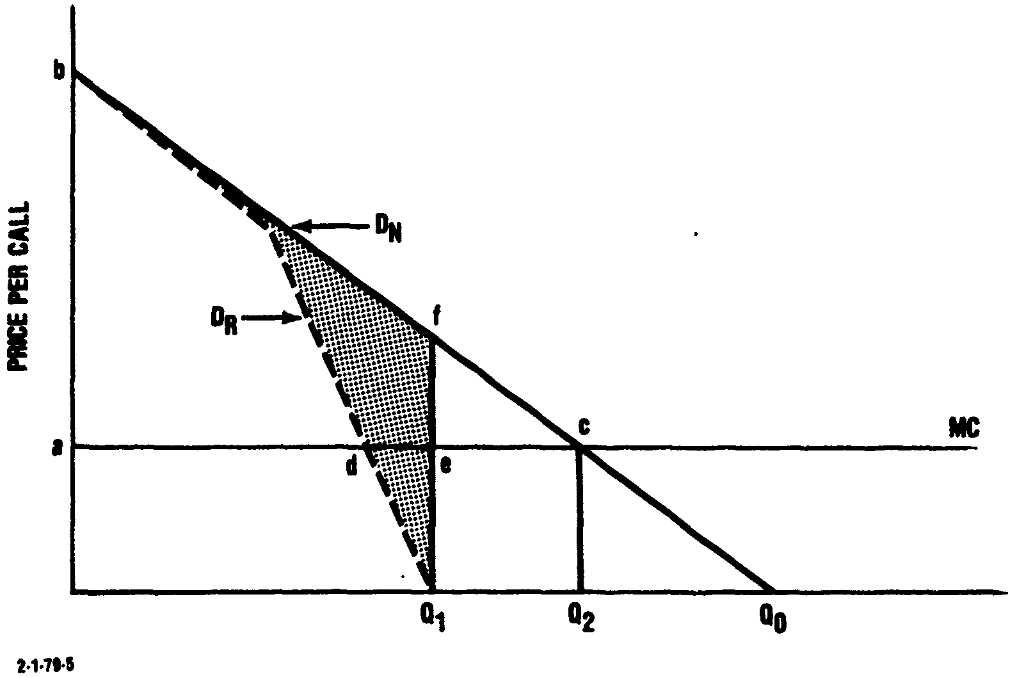



Figure 2. NOTIONAL AND REALIZED DEMAND FOR TELEPHONE SERVICE (WITH PRE-EMPTION)

With precedence and pre-emption, the realized demand curve lies much closer to the notional demand curve at the upper end than it does without precedence. The welfare costs of congestion (the shaded area) are smaller than in the case with no pre-emption. Both the foregone consumers' surplus and the deadweight loss due to handling calls whose value is below the cost of service are less than in the situation depicted in Figure 1.

The location of the realized demand curve will also be affected by the behavior of callers who do not succeed in placing a call the first time they try. Multiple attempts will shift the notional demand curve out from the origin with the

[1]It will not always be true, of course, that calls made on a higher precedence line are intrinsically more valuable than those made on a low precedence line.

nature of the shift depending upon who is doing the redialing. If people making low valued calls increase their attempts relatively more than those placing high valued calls, both the notional and the realized demand curves will be skewed toward low valued calls. Such a situation is illustrated in Figure 3 when there is no pre-emption capability. N is the nominal demand curve after multiple attempts are taken into account. It shifts outward more at the lower end as more low valued calls are repeated. The result is that the realized demand curve is also skewed and, with relatively more low value calls being completed, the welfare costs increase relative to what they would be with no redialing. (The figure still does not include the additional costs directly associated with redialing. These would need to be calculated separately.) Adding pre-emptive capability to the system would produce the same beneficial effects that are illustrated in Figure 2.

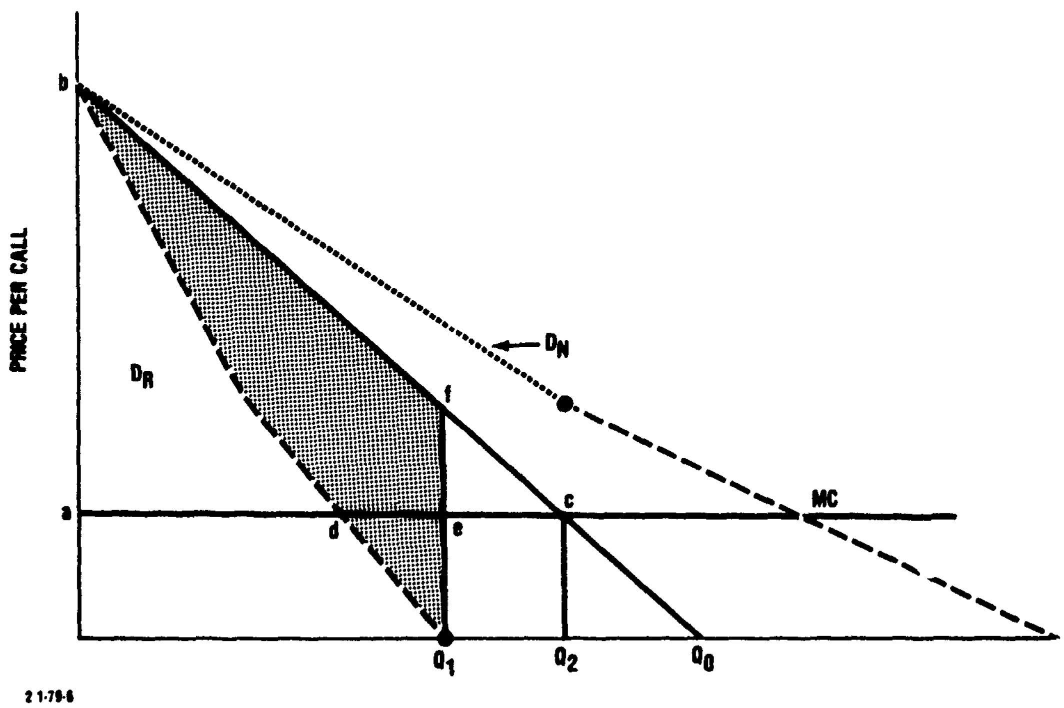
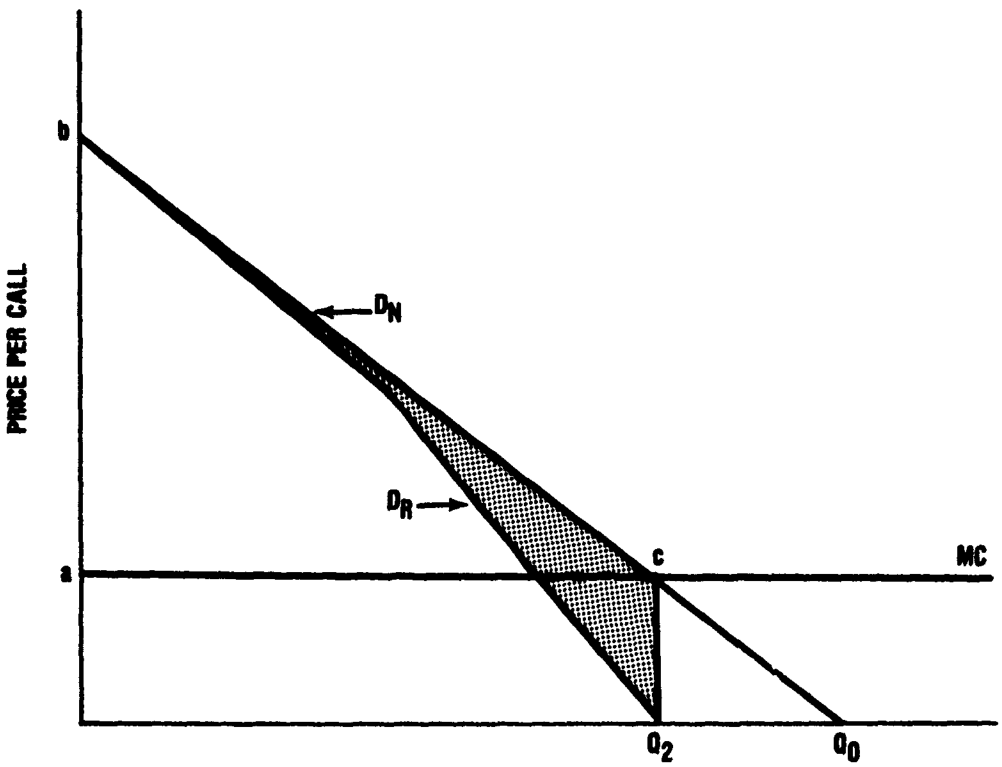



Figure 3. NOTIONAL AND REALIZED DEMAND FOR TELEPHONE SERVICE WITH REPEATED ATTEMPTS BY LOW-VALUED CALLERS

There is one other question that our model can also shed some light upon--the feasibility of determining the optimal quantity of service under current conditions. According to the diagrams in Figures 1 and 2, the optimal service quantity would be $Q_2$. In the absence of charging for calls, however, there is no way of knowing whether capacity is actually at the optimal level $Q_2$ or not because even if it were, congestion would still be present. In fact, congestion would be an essential feature of the system as long as zero price were charged. It would be the only way in which our hypothetical optimal amount of capacity could be allocated. The existence of welfare costs even when capacity is optimal is illustrated in Figure 4. The capacity of the system is at $Q_2$ and there exists pre-emptive capability so that high valued calls do get through. With a zero price the excess demand is $Q_0 - Q_2$. The cost of this excess demand is represented by the shaded triangle $acQ_2$.




2-1-79-7

Figure 4. NOTIONAL AND REALIZED DEMAND FOR TELEPHONE SERVICE (WITH PRE-EMPTION AND OPTIMAL CAPACITY)

Having examined the theory behind congestion pricing and usage-sensitive pricing, we can now move on to see how some of the changes in price structure we have discussed in such a general way might be calculated and what level of charges users might expect to face if usage-sensitive pricing were instituted. We shall also look at ways in which service might be improved and costs reduced as a result.

# Chapter III

# USAGE-SENSITIVE COST ALLOCATION: DISTANCE, TIME AND PRECEDENCE

## A. INTRODUCTION

In the first two chapters of the study we examined the characteristics of AUTOVON, made suggestions about ways in which the current access charge structure could be improved, discussed the theoretical justifications for having a usage-sensitive pricing system, and analyzed the effects of having pre-emptive capability. In this section we build upon the theory of Chapter II and describe the methodologies and data that would be needed to institute usage charges. In illustrating the methodologies we also provide some rough estimates of the level of charges that might be expected. The estimates we have made apply only in CONUS but the methodology could be adopted easily to provide similar estimates for the overseas networks.

For an organization such as the DoD where callers do not pay for their calls, usage-sensitive pricing has three basic objectives. First, it should induce subscribers to choose the number of access lines and the precedence that best suits their traffic requirements. Second, it should allocate the operating costs of the system to the agencies that actually use it and give them sufficient information so that, in turn, they can (if desired) impose controls, regulations, or costs directly on the individuals or agency subdivisions that are doing the calling. Third, it should furnish reliable data for the organization supplying the service to use in deciding

how much of the service to provide and when to adjust capacity. If prices of particular aspects of service are directly related to costs, and excess demand exists, the supplier can more confidently decide what adjustment is necessary.

In order to achieve these three goals, a pricing system must reflect the costs of various services. This in turn requires accurate accounting for all the direct and indirect costs of the service. Once such an accounting structure has been constructed, it becomes necessary to determine the rules that define units of measure of service and then assign costs to these units of service. One of the most important aspects of the process is to develop a defensible methodology for billing and assigning costs so that future changes in technology, equipment costs, and usage can easily be accommodated in adjusting rates.

In the AUTOVON system there are three major components of cost: access, usage, and precedence.[1] The access-related elements of cost provide the capability to receive and originate calls over the AUTOVON network. They are primarily attributable to facilities provided at individual user locations or through consolidated switchboard facilities. Under the present allocation of responsibility between DCA and users, the access costs are paid for directly by subscribers.

The usage-related components are those associated with the common backbone network that consists of switches and connecting trunks. The number of switches and trunks is a direct function of the amount of traffic that must be carried.

The precedence-related elements are those pieces of equipment the system requires in order to permit calls of higher precedence to pre-empt calls of lower precedence. The amount

[1]We are referring here only to the direct costs of providing service, exclusive of any indirect or congestion costs.

of such equipment does not vary according to the number of precedence calls; once installed it simply offers capability. It does increase directly with the number of switches and trunks, however, and is thus a function of total traffic.

## B. ACCESS

In order to obtain access to the AUTOVON systems, a subscriber must lease from a common carrier a trunk line connecting his facility to a backbone switch. The principal components of the access cost are the trunk termination charges at the user PBX and the AUTOVON switch and the trunk mileage between the PBX and the switch.[1] If the PBX and the switch are in the same exchange area, there are no trunk mileage charges. The monthly termination charges are as follows:

| | | |
|---|---|---|
| \$ 46.55 | = | The termination cost per trunk terminal |
| \$ 43.30 | = | The Telpak service charge per terminal |
| \$ 89.85 | = | Subtotal |
| 16.20 | = | Multiple level pre-emption charge per terminal |
| \$106.05 | = | Total. |

The total termination charges for an access line would be twice these figures, or \$179.70 for a line with no pre-emption. The average cost per access line including mileage charges is \$218.00.[2] Precedence charges are included because they are associated with the access line itself and thus can be allocated directly to the subscriber. All of these access costs are currently paid by the subscriber through DCA.[3]

---

[1]The exact cost of the termination arrangements may depend upon the nature of the switch that provides service to the user location and, in some instances, upon the jurisdiction in which the user site and the switch or switchboard are located.

[2]Source is DCA.

[3]In a later section we shall analyze the desirability of reducing these access charges to subscribers and collecting some portion of the access costs through usage-related tariffs.

## C. USAGE--DISTANCE AND TIME

For the most part the costs of AUTOVON backbone are determined by the volume and kind of traffic generated by the users. In order to maintain the standard of service at a particular level, a certain number of trunks and switches are needed. An increase in traffic requires more equipment. The cost components of the AUTOVON backbone system are similar in nature to those associated with access, except that there is a wider variety of equipment and charges. Within CONUS the costs are almost entirely comprised of switch connections plus mileage for the trunks. The monthly termination charges are:

$46.56 = Cost per trunk terminal
43.30 = Telpak service charge per terminal
$89.85 = Total termination charge.

Doubling this we get $179.70 per trunk as the total termination charge. In addition, there is the trunk mileage charge of 56.8/mile. The average trunk length is 640 miles and the average monthly mileage charge is $366.00 per trunk. Thus, the total average cost per trunk, exclusive of pre-emption capability is $545.70. With 7,433 trunks, this amounts to $4,056,000 per month that should be allocated to subscribers in accordance with the degree to which they use the system.[1]

There are two characteristics of phone calls that impose costs, distance and holding time. Allocating on the basis of usage requires charges to be a function of these two factors. AUTOVON calls within CONUS can be divided into two categories, those that are between subscribers connected to a single switch and those between subscribers at different switches. The first type of call uses no backbone trunks and, given that the subscribers have already paid the connectivity costs of their access

[1]There are four switches leased from independent phone companies whose total cost is $3,169,000 per year. These switches are not included in the calculations.

lines, should pay no part of the backbone costs--these calls should be free.[1] The long distance calls that require at least two switches plus the connecting trunks, however, should pay for the costs of the trunks they use. As discussed earlier, these costs are of two kinds, termination and mileage. Most of the switches are directly connected by trunks to each other switch, which means that if a call follows the most direct path, it will incur the mileage and termination costs for only a single trunk, regardless of the distance called. Thus, each call should bear its share of the monthly charges of 56.8¢ per mile and $179.70 for terminations. Since the capacity of a trunk is fixed per unit time, each call should be charged at a flat rate per minute to cover the termination costs, plus a variable charge per minute that depends upon the distance.

It would be far too cumbersome to charge each call for the exact distance, however. It makes much more sense to do the same thing commercial carriers do and categorize calls within certain distance bands. The choice of distances would be arbitrary, although an examination of the distribution of calls by distance might offer some guidelines. In the absence of specific information one could select something like the following:

Band 1 = intraswitch
Band 2 = less than 300 miles
Band 3 = 300 to 1,000 miles
Band 4 = over 1,000 miles.

Each switch pair would be classified as band 2, 3, or 4.

In order to estimate the total charge per minute that would be required for calls in each band, it is necessary to

[1]There is some possibility that making intra-switch calls free would provide some incentive for long access lines to avoid using the backbone. This could easily be controlled, if desired, by insisting that subscribers connect to the nearest switches. In some cases, however, such direct connections might be advantageous since they would free up capacity on the backbone.

perform two calculations. The fixed charge per call minute would be determined by the total number of call minutes independent of distance. Thus, if we let B be the total monthly charge for all terminations in the backbone (B = $1,335,710) and Y be the total number of minutes of conversation using CONUS trunks during the month, the fixed cost per minute would be:

$$a = \frac{B}{Y} .$$

Computation of the mileage charge would be slightly more complicated and would require knowledge of the mean call distance within a mileage band, the number of calls, and the mean holding time within each mileage band. If we let $x_i$ be the mean distance per call within band i, $y_i$ be the number of calls, and $t_i$ be the mean holding time, the total number of call-minute-miles for the CONUS system would be:

$$Z = \sum_{i=2}^{4} t_i y_i x_i . \tag{1}$$

If D is the monthly mileage costs of trunks (D = $2,720,478), the cost per minute per mile would be:

$$b = \frac{D}{Z} . \tag{2}$$

To convert this cost into a per minute cost for each band, $d_i$, it is only necessary to multiply b, the cost per minute, by the average mileage in the band:

$$d_i = bx_i . \tag{3}$$

The total cost per minute within each band, $C_i$, would then be:

$$C_i = a + d_i . \qquad i = 2,3,4 \tag{4}$$

The per minute charge for local calls would be zero.

[1]The mean distance per call is a weighted average of call distances when the weights are the number of minutes per call at each distance within the band.

The methodology described above implicitly takes into account the fact that because of busy circuits or for other reasons, many calls do not get routed directly between two switches but may in fact pass through three or more. The system is engineered so that approximately 30 percent of all calls are overflow calls that do not go direct. All costs of the system are taken into account, however, and therefore the costs of providing alternative circuit capacity are included as well. Since there is no way of predicting or identifying which calls actually use indirect routing, these costs should be allocated to all calls. In addition, pure change determines which calls go direct and which do not.

Throughout the preceding discussion we have assumed that data are available both on total minutes of holding time for successful calls and on the joint distribution of completed calls by distance and holding time. As a practical matter, this information is not readily obtainable at present; however, it is possible to make some reasonable estimates of total time and use sample data to arrive at rough approximations of the distribution by distance and the mean holding time for calls.

In the absence of data on numbers of calls and average holding period, total minutes of holding time can be estimated using data from the AUTOVON Network Administration Report (ANA).[1] This report provides information on the percentage of occupancy of the total trunk network in the CONUS system. The sample covers five days every other month; occupancy is reported on an hourly basis for the eight hours between 9:00 AM and 5:00 PM central time. We can use the figures from the Report covering February 6 through 10, 1978 to illustrate how the methodology could be used. Table 9 shows the occupancy figures for the eight hour period.[2] Since the occupancy figures are available

---

[1]See Appendix B for a description of this report.

[2]These occupancy rates resulted in a grade of service of P.19.

only for the eight hour business day, we must either accept this period as containing all the calls in which we are interested, or make some upward adjustment to take account of calls made at other hours. We choose to do the former. There is excess capacity during the non-business day so marginal cost pricing would call for them to be billed at zero.[1] In addition, off hour calls constitute a relatively small fraction of the total.

Table 9. OCCUPANCY RATES FOR CONUS TRUNKS
FEBRUARY 6 THROUGH 10, 1978

| Time Period | Percent |
|---|---|
| 9 - 10 AM | 60 |
| 10 - 11 | 77 |
| 11 - 12 | 80 |
| 12 - 1 PM | 62 |
| 1 - 2 | 74 |
| 2 - 3 | 80 |
| 3 - 4 | 76 |
| 4 - 5 | 58 |
| MEAN | 71 |

With 7433 trunks, an eight hour business day has 59,464 hours or 3.568 million minutes of calling time available. At an average occupancy of 71 percent, 2,533,000 minutes are used.[2] The total terminal cost for 7433 trunks is $1,335,710 per month. There are an average of 21 working days per month so the terminal cost per working day would be $63,605. If this is divided by the

[1]This statement assumes that there are no variable costs associated with calls and that a zero price does not shift the peak period from the business day.

[2]The actual number of trunks in February 1978 was 7680. If the occupancy figures remain constant, however, the calculations would yield the same results since terminal costs increase linearly with trunks.

2.533 million minutes of use, the cost per minute is 2.51¢.[1] This approximates b, the fixed charge per minute that would be assessed all long distance calls using CONUS facilities regardless of the call distance. The 2.51¢ probably understates somewhat the charge that should be made for *completed* calls since the occupancy figures include all attempts as well as completions, but it is sufficient for present purposes.

A more difficult data task confronts us when we attempt to estimate the trunk cost per minute/mile. For this we need the joint distribution of calls by distance and holding time. Neither of these distributions is currently available.[2]

It is possible, however, to make very rough estimates of the per minute charges that would be applicable to long distance calls by making some assumptions about appropriate band widths and the mean distances within each band.

First, suppose all long distance calls were to be charged a single price regardless of distance. In this case the average call distance becomes irrelevant and the total trunk costs must be assigned to the total long distance calls. If the total monthly mileage cost of trunks is $2,720,478, and there are 21 business days per month, the trunk cost is $129,547 per day. As we saw earlier, at an occupancy rate of 71 percent, there are 2,533,000 minutes of long distance calls per day. Dividing one figure by the other, we arrive at a trunk cost of $.051 per minute for long distance calls. This would be the charge within CONUS if there were no distance discrimination other than that between inter- and intra-switch calls.

---

[1]If the cost of leased switches ($3,169,000 per year) is included, per minute cost rises to 3¢.

[2]There is some possibility that the ANA data, which give traffic from each switch to all other switches, may provide sufficient information to make a relatively accurate estimate. Assuming call length does not vary with distance (which the FTS study found *not* to be true) it should be possible to calculate the proportion of calls in each distance band and apply this to the total call time (calculated above) to arrive at number of calls in each band.

If there were discrimination among distances, however, and the distance bands used were those postulated earlier, the charges would be as shown in Table 10 assuming that the mean distances within the bands were as shown.

Table 10. ESTIMATE OF AUTOVON VARIABLE LONG DISTANCE CHARGES ($ per minute)

| Distance Band | Mean Distance | Charge |
|---|---|---|
| Intra-switch | 0 | $.000 |
| Less than 300 miles | 200 | .016 |
| 300 to 1,000 miles | 644 | .051 |
| Over 1,000 miles | 1088 | .086 |

These figures are obtained using Equations 1, 2, and 3. The daily cost is $129,547. The number of minute miles is obtained by multiplying the number of trunk minutes used (2,533,000) by the average trunk length (644). The product is 1631 million minute miles. The cost per minute mile is $.00008. Multiplying this by the average mean distance yields the charge figures in Table 10. It is essential to make the further assumption that the mean overall distance for all these bands is also 644 miles. Otherwise the $.00008 figure must be recalculated.[1]

The total cost per minute of a long distance call within CONUS using these assumptions would be:[2]

[1]See Economics and Technology, Inc., "Pricing Policies and Billing Concepts for the FTS Intercity Voice Network," Boston: Dec. 1977 (report prepared by GSA).

[2]The charges calculated for FTS (which offers a better grade of service and has a lower occupancy rate) for similar distances were:

| | Band 2 < 250 | Band 3 250 - 1000 | Band 4 > 1000 |
|---|---|---|---|
| Fixed Cost | $.050 | $.050 | $.050 |
| Mileage Cost | .016 | .060 | .189 |
| | $.066 | $.110 | $.239 |

| | Band 1 Local | Band 2 < 300 | Band 3 300 - 1000 | Band 4 > 1000 |
|---|---|---|---|---|
| Fixed Cost | $.00 | $.025 | $.025 | $.025 |
| Mileage Cost | .00 | .016 | .051 | .086 |
| Total | $.00 | $.041 | $.076 | $.111 |

These total costs would also be the starting point for calculating the cost of international calls as well. The international costs would simply be added on to these to come up with a total for an overseas call from a point within CONUS to a point outside, or from one overseas point to another.

## D. PRECEDENCE

As was demonstrated earlier in Chapter I, the current charges for precedence are for the most part a means of allocating the costs of overseas calls. The proportion of subscribers with a high precedence designation is much larger among lines with overseas capability than among those with only CONUS capability. The higher precedence is required in order to make overseas calls.

One must assume that, strictly speaking, allocating long distance costs is not what is conceived of as the function of precedence. A system of charging based on usage costs would allocate the long distance costs to the long distance users, regardless of precedence, and would allocate to the precedence callers the cost of providing pre-emptive capability *plus* the costs they impose on others by pushing to the head of the queue and interrupting conversations.

The actual cost of providing precedence is a relatively small part of the total budget of AUTOVON. It is assessed on each trunk and access line with pre-emption capability and is $19.45 per month per termination, or $38.90 per trunk and $19.45

per access line.[1] The access line charges are paid for by the subscribers, but the trunk termination charges for precedence are part of the AUTOVON budget and under a user charge system would need to be allocated to those subscribers with precedence capability.

It is not obvious whether the costs of pre-emption should be allocated on the basis of capability or usage. For a given size system with a certain total capacity, the cost of pre-emption is fixed regardless of whether 10 percent or 50 percent of the calls are precedence calls. The implication of this is that the pre-emption costs should be allocated on the basis of capability rather than usage. On the other hand, the cost of pre-emption does change with total capacity so that, as the total number of calls increases or decreases sufficiently to require adjustment of backbone size, pre-emption costs change as well. In this respect, the pre-emption costs are identical to trunk mileage or connection costs and thus should be allocated on the basis of usage. Usage charges for precedence do provide incentives to use lower precedence in making calls and, as a result, may be preferable to charging on the basis of capability. Nevertheless, we shall indicate how the precedence costs could be allocated under either method, beginning first with usage. There is no economic rule to tell us how to allocate the costs among the different precedence levels. The current weightings for precedence charges of 4, 3, and 2 for flash, immediate, and priority, respectively, are arbitrary; others could be chosen. In our examples, however, we shall use them. If we assume that none of the precedence cost should fall on routine calls, the weights can be divided by two so

[1]There is only a single termination fee, at the switch, for access lines. The pre-emption fee is not assessed at switches that are leased.

that the minutes of flash, immediate, and priority calls would be weighted 2, 1.5, and 1, respectively.[1]

The total monthly cost in CONUS of providing precedence service is \$38.90 times the number of trunks (7433), or \$289,144. On a 21 day basis, the daily cost is \$13,769. If we let C be the total cost of precedence, x the number of minutes of flash calls, y the minutes of immediate calls, and z the number of minutes of priority calls, the precedence charge per minute for a priority call would be:

$$C_z = \frac{C}{2x + 1.5y + z} .$$

The charge per minute for immediate calls would be:

$$C_y = 1.5C_z ,$$

and that for flash would be:

$$C_x = 2C_z .$$

At present we have no information on the total number of call minutes by precedence, but we can perform some hypothetical calculations that are informative. Suppose we assume that 20 percent of total call minutes in CONUS are the equivalent of priority precedence calls (i.e., 20 percent includes flash and immediate weighted at 1.5 and 2 times priority, respectively). The additional charge per minute for a priority call would be:[2]

---

[1]One might argue that routine lines with pre-emptable capability might receive some benefits from this fact since they could be interrupted to receive important messages but there is no way of allocating user costs to called parties.

[2]As discussed in "Usage Sensitive Pricing," the average month consists of 21 working days and the average number of call minutes per day is 2.533 million. Twenty percent of 2.533 million is 506,000. This is not a wholly realistic figure. Of the CONUS lines, 13 percent are of precedence above routine. If 13 percent of total call minutes were also precedence calls, this would be 329,300 minutes of precedence calls. There are any number of feasible combinations of flash, immediate, and priority calls which, when (continued)

$$C_z = \frac{\$13,769}{506,600} = \$.027/\text{minute.}$$

The charge for an immediate call would be:

$$C_y = 1.5C_z = \$.040/\text{minute.}$$

The charge for a flash call would be:

$$C_x = 2C_z = \$.054/\text{minute.}$$

These charges per minute would be added to the per minute charges already estimated for long distance calls. If fewer precedence calls were made, the charge per minute would rise. The converse would be true with more precedence calls.

This method for estimating the charges to be assessed against precedence callers does not take into account the costs imposed on non-precedence callers as a result of having their conversations interrupted. Assignment of a dollar value to this cost is arbitrary but should probably be done on a per call rather than a per minute basis. The cost comes from the interruption, not from the length of the pre-empting call. If it were possible to determine and record whether or not a precedence call actually interrupted another call in the process of being completed, one could assign a single fixed charge for all precedence levels, for example $1.00, which would be assessed only when interruption occurred. If it were impossible to record actual interruptions, the fixed charge per call for different precedences should reflect the probability that a call does interrupt another call. Since priority pre-empts only routine, the probability it will interrupt a conversation is less than the probability that an immediate call will interrupt, which, in turn, is less than the probability for a flash call.

---

weighted by 2, 1.5, and 1, would bring this figure up to the equivalent of 506,000 priority call minutes. This figure also ignores any intra-switch calls. The only pre-emption possible on intra-switch calls, however, is that of the call recipient since no trunks are used. Thus, the access line charges take into account any pre-emption costs attributable to intra-switch calls.

If one were to postulate that the average cost in terms of time and utility of an interruption to the person pre-empted were $1.00 and the probabilities of interruption for priority, immediate and flash were 1/4, 1/3 and 1/2, then the fixed charge involves first, measuring the cost of interruptions, and second, determining the frequency with which interruptions occur for calls of different precedence levels. The revenue collected through the fixed charge would not correspond to any real costs and therefore should be used to reduce the average charge per minute assessed against all calls. In this way the pre-empted users would be compensated for the costs imposed on them. Since low precedence heavy users would be pre-empted more often than light users, reducing the charge per minute would increase their relative compensation.

There is the possibility that charging for precedence on the basis strictly of usage, particularly when a fixed charge is assessed for interruptions, could lead to a situation in which the number of precedence calls falls. This in turn could lead to higher per minute charges for precedence, which in turn could lead to a further decline in the number of precedence calls which could lead to a still higher per minute charge for the calls, with either no equilibrium or an equilibrium at a very high per minute charge for precedence. Although this result is unlikely, occurrence would provide a justification for allocating the costs of precedence capability at least partially on the basis of connectivity or through some other means.

Instead of charging for usage, if precendence costs were allocated on the basis of an access fee it would be necessary to charge subscribers monthly as a function of the level of precedence for their lines. Assuming that routine lines should not bear any of the backbone costs of precedence (even if pre-emptable), we could weight the precedence levels in the same way they are now weighted, 2/1.5/1 for flash, immediate and

priority.[1] Although the charges are levied only in CONUS and on overseas trunks that connect to CONUS switches, all lines having access to CONUS share the charges. The numbers of lines with access to CONUS of each level of precendence are shown in Table 11.

Table 11. ACCESS LINES TO CONUS BY CAPABILITY AND PRECEDENCE

| | CONUS Area | CONUS/ Europe | CONUS/ Pacific | CONUS/ Caribbean | Global | Total |
|---|---|---|---|---|---|---|
| Flash[a] | 866 | 44 | 76 | 16 | 150 | 1172 |
| Immediate | 758 | 165 | 202 | 23 | 116 | 1264 |
| Priority | 528 | 25 | 70 | 24 | 24 | 671 |
| Total | 2172 | 234 | 348 | 63 | 290 | 3107 |

[a]Includes phone data and send-only PBX.

If these lines are weighted 2/1.5/1 for flash, immediate and priority, the 3107 lines are the equivalent of 4911 priority lines. The total backbone cost of precedence service is $289,144 per month.[2] Allocating this in accordance with the weights would yield the following monthly charges for precedence service:

| | |
|---|---|
| Flash | $117.75 |
| Immediate | 88.32 |
| Priority | 58.88 . |

These charges would substitute for the per minute charges discussed earlier that covered only the out-of-pocket costs of the pre-emptive capability of AUTOVON. (It should be emphasized that these particular figures are not hypothetical but are based on the actual cost of precedence and the number of precedence lines.)

[1]This is equivalent to 4:3:2:1 for flash, immediate, priority, and routine except we have normalized priority as 1 instead of routine.

[2]This is $38.90 times the number of trunks, 7433.

One might also wish to charge an access fee to cover the costs imposed on pre-empted users. The calculation of the appropriate charge under the assumptions made earlier (or any other set of assumptions) is fairly easy. The difficulty would come in deciding on an appropriate figure as the cost of an interrupted call. Earlier, we arbitrarily assigned a cost of $1.00 per interruption and assumed the probabilities of pre-empting were 1/2, 1/3 and 1/4 for flash, immediate and priority calls. The monthly fixed fee that would allocate these same hypothetical costs to priority line users would be as shown in Table 12.[1]

It is apparent from the figures in Table 12 that if the number of pre-emptions is very large, one need not assign a very high inconvenience cost to being pre-empted (in this case $1.00) in order for the fixed fee that allocates these costs to become rather high. In our hypothetical example, these fees are approximately double the fees that cover the real cost of precedence capability. This is a facet of the pre-emption question that surely deserves further attention--what are the costs imposed on those people interrupted by users of higher precedence?

---

[1] It is a simple matter to define a functional relationship between the fixed fee that should be charged for each line and the elements that determine it. Suppose we define:

$Q_i$ = monthly fee for line of precedent i

$N_i$ = number of calls per month of precedent i

$P_i$ = probability of pre-empting a lower precedent line

$C$ = cost of being pre-empted

$L_i$ = number of lines

$T$ = total number of calls

$L$ = total number of lines

Then for any precedence the monthly fee would be $Q_i = \frac{N_i P_i C_i}{L_i}$.

If we assume that the number of calls of each precedence is proportional to the number of lines, this becomes

$$Q_i = \frac{T}{L} P_i C .$$

Table 12. ESTIMATED PRE-EMPTION COSTS

| Precedence | Number Calls | Probability of Pre-empting | Number of Calls Pre-empted | Cost of Pre-emption | Number of Lines | Monthly Fee |
|---|---|---|---|---|---|---|
| Flash | 505,333 | .5 | 252,666 | $ 252,666 | 1172 | $215.59 |
| Immediate | 531,930 | .333 | 177,133 | 177,133 | 1264 | 139.04 |
| Priority | 292,562 | .25 | 73,140 | 73,140 | 671 | 109.00 |
| TOTAL | 1,329,825 | | 502,939 | | 3107 | |

[a]The number of calls of each type is consistent with a total number of priority-equivalent calls of 101,320 per day or 2,127,720 per month and is proportional to the number of lines of each type. The number of calls is obtained by assuming the average holding time is 5.0 minutes and dividing the total number of calls per month by 5.0.

There is one aspect of the current method of charging for precedence that DCA is powerless to affect. The single connectivity charge of $19.45 for access lines applies to lines that are pre-emptable as well as those that can pre-empt. All lines of precedence higher than routine and approximately one-third of the routine lines have pre-emption capability. All lines with pre-emption capability pay the same termination charge even though the routines can only be pre-empted and the values of the other precedence levels are clearly different from each other.

With the current system where subscribers pay all costs associated with the access line itself, there is no other way in which these costs can be allocated. If, on the other hand, access lines were also included in the backbone and responsibility for them given to DCA, the pre-emption charges for access lines might be set at levels that more nearly reflected the value of different precedence.

## E. ACCESS CHARGES VS. USAGE CHARGES FOR DIRECTIONALITY

DCA controls and charges only for the AUTOVON backbone. Virtually all of the resources the backbone operation requires are a function of the amount and kind of service furnished. If more traffic must be accommodated, more trunks must be leased. The size of the system is sensitive to usage; only the overhead costs could be considered allocable on the basis of access charges, and these amount to approximately five percent of the total. Subscribers already pay for having DCA subsidize these access line costs, particularly if they wish to encourage services to increase the numbers of lines they sign up for. Currently, subscribers pay all non-backbone charges for the access lines they have amounting to an average $218 per month per line. The backbone charge for the least costly access line, a two-way area routine, is $253 per month; that for the most costly, a global two-way flash, is $4,968. Thus, the access line cost is, in one case, nearly equal to the backbone charge, while in the other it is only one-twentieth.

The present practice of offering in-only lines at a zero backbone charge is effectively equivalent to cutting in half the cost of a routine access line because the subscriber must still pay on average the monthly line charge of $218. Thus, under the current system of charging, there is still a disincentive for subscribers to sign up for in-only access lines. They are not free goods. One must wonder therefore if the policy really is an effective and efficient one. It provides incentives for subscribers to select a mix of lines that is cost-effective in terms of providing what they consider to be the services required. But since the one-way-in access lines are not truly free and, in fact, cost on average over $2500 per year, there is no reason why a subscriber should sign up for unlimited numbers merely to provide other subscribers with

increased access to his own people.[1] Thus, the incentive effects of a zero backbone charge for one-way-in lines are not likely to be very strong except in terms of distorting choices. The greatest incentives for acquiring in-only access lines will go to those with low mileage access trunks, but even the cheapest line will be $180 per month.[2]

As was argued earlier, if the present system of charging is retained, the one-way-in access line charge should be made positive and probably should be raised so it is equal to or nearly equal to the two-way charge. The difference, if there is one, should reflect the differences in engineering efficiency between a one-way and a two-way line within a properly configured system.[3] In this way, the choice of mix of lines will reflect more closely the efficient choice.

On the other hand, if a usage-sensitive charging system is adopted, the rationale for a zero backbone charge for in-only lines will disappear completely because virtually all access costs can be eliminated. Approximately five percent of the backbone costs are overhead and non-allocable on the basis of usage; if this five percent were the only portion collected through a connectivity fee, the monthly cost of a two-way routine line would fall from the current $253 to approximately $12.50. A zero cost on in-only would provide virtually no incentive to choose in-only instead of two-way.

In addition, if usage sensitive pricing systems were adopted, it would be feasible (if desired) to consider subsidizing

---

[1]In the private sector, businesses often provide toll-free lines for customers to call in, but it is difficult to find an analogy in the military, particularly at present where all calls are toll free.

[2]One would in fact hypothesize that the ratio of in-only lines to total lines increases as the access line length decreases. This question is worthy of further study.

[3]See the DCA Traffic Engineering Practices manual for the method in which efficiency is measured. See Appendix A for a discussion of ways in which one-way lines might be potentially valued.

the access line charges. For example, DCA could pay 20 or 30 percent of the fees for a two-way routine line. Such subsidization would encourage subscribers to increase the number of access lines they sign up for without leading to distortions in the mix of lines they select. Subsidizing access line costs would simply result in higher fees for actual use. The appropriate degree of subsidization would be a function of the extent to which additional access lines would reduce congestion for a given size backbone. The choice between access fee and usage charge could become a policy variable for DCA. Higher usage fees would tend to inhibit the number of calls while lower access costs would lead to a larger number of access lines. The net effect of either type of response would be less congestion for a given amount of trunk and switch capacity. Total costs, including access line costs, might increase or decrease depending upon the relationship between the change in backbone costs and the change in access line costs.

There seems to be no way at present, however, of predicting what functional relationships might exist between the allocation of charges and the selection of access lines and, ultimately, congestion. If a usage charge system were adopted, experiments in subsidizing access line fees could be undertaken to permit the response to be evaluated. If DCA were to take over responsibility for configuring access lines as well as the backbone, as has been recommended numerous times, decisions on access line fees would become a purely internal matter and other kinds of pricing could be considered, such as a fixed cost per access line independent of actual trunk lengths. Although DCA currently is not in a position to make such decisions, it would be valuable to have an extensive analysis of the advantages and disadvantages of such alternatives.

If the current pricing system is retained and all backbone costs continue to be collected through a connectivity fee,

elimination of the zero price on in-only lines could result in a decline in the cost of a two-way routine line. As of 30 April 1977, there were 7247 two-way routine lines nearly all of which were in CONUS, and 4579 in-only lines, also in CONUS. If in-only lines were to be charged the same as two-way routine and the total number of lines were unchanged, the monthly charge would fall from $253 to approximately $206. The average total cost (including the access line) for a two-way line would fall from $471 to $424, while the average cost for an in-only line would rise from $218 to $424. There would be an incentive for subscribers to acquire more two-way lines; there would also be an incentive to drop in-only lines altogether, but given the greater efficiency of the two-way lines, it is not clear whether this would increase congestion or not. The charges for area plus and global lines would all decline.

## F. RESPONSIBILITY, CONTROL AND USER RESPONSE TO USAGE PRICING

In contemplating whether or not to institute a billing system for AUTOVON services that includes usage charges, one must take into account one very important aspect of the way in which the system is organized and services provided--the fact that DCA's authority and responsibility are limited to the backbone portion of AUTOVON. It has virtually no control over any activities outside the backbone. This is an important point to keep in mind when assessing what DCA can do in terms of charging for usage and the effects su h charges might have. (It also brings up the question of whether DCA's responsibility should not be extended beyond its present limits--a question discussed briefly above.)

The objective that DCA could achieve with the greatest degree of certainty in imposing usage charges is improvement of the equity of the cost allocation system. It is also possible, however, that such charges could improve the efficiency with which communications resources are used by influencing

the behavior of the major users--the Services and the agencies. A change in the structure of charges cannot directly influence the behavior of the callers. Any actions that are taken which directly affect callers must be taken at the agency level. The following discussion preserves this distinction between major users and direct users and looks both at the effects of various billing systems on agency budgets and incentives, and at the potential actions that agencies might undertake in response to the incentives provided.

To examine the potential benefits of instituting usage-sensitive charges and reducing access fees, we must separate them into (1) direct benefits that may be expected from charging user agencies in different ways, and (2) indirect benefits that may accrue if the agencies react to the new charges by attempting to influence callers' behavior.

In evaluating the impact of instituting usage charges, it is useful first to review the model we have used and then consider some alternative assumptions about how user agencies might respond to changes in the pricing structure. If we ignore precedence, we can assign costs to three categories--direct costs per calling minute, direct costs per connection, and overhead costs. In symbols these would be:

$a$ = direct costs per calling minute
$b$ = direct costs per access line
$F$ = fixed costs.

The system's total cost function is:

$$C = F + aX + bY.$$

## Chapter IV

## CONCLUSIONS AND RECOMMENDATIONS

Usage-sensitive pricing for the AUTOVON system would appear to offer a number of benefits that can be categorized under three different headings. First, it would allocate more equitably the costs of the system. Second, it would provide incentives for users to utilize the system more efficiently. Third, it would increase the accuracy of information received by DCA and permit it to manage the system more efficiently in responding to changes in demand. Our primary recommendation is that serious consideration be given to the adoption of a usage sensitive pricing system similar to the one described in this study with a low access fee and call charges based on time, distance and precedence.

The main reason we cannot be more firm in recommending the adoption of a usage sensitive pricing system is that we have virtually no information on the cost of installing the Automatic Message Accounting system that would be required. The last time an estimate of the cost of AMA was obtained was in the late 1960s and the estimated cost then was $3.3 million per year. The figure would undoubtedly be different now. Thus, we recommend an updated estimate of the cost of instituting AMA in order to determine whether the potential benefits in increased grade of service and reduced system costs outweigh the cost of having AMA.

In addition to looking at the value of instituting usage-sensitive pricing we also examined the current rate structure and the way in which it allocates system costs among users.

There are a number of observations we can make about the present rates as well as about usage-sensitive pricing.

## A. THE CURRENT RATE STRUCTURE

**The average charges for different service capabilities do not reflect the costs of providing those capabilities.** The total revenue collected from users with only area capability, such as CONUS or Europe, is not adequate to cover the cost of providing area service. On the other hand, the total revenue collected from users with area-plus and global capabilities exceeds the cost of providing area-plus and global service. CONUS subscribers pay only 89 percent of their costs, Pacific subscribers pay 64 percent, and Europe subscribers pay 74 percent. CONUS-Europe and CONUS-Pacific subscribers, however, pay approximately one-third more than their costs and global subscribers pay 25 percent more. In evaluating what these distortions mean in terms of who is paying for the system and what adjustments might be appropriate, we arrive at the following conclusions.

**Precedence charges serve primarily to allocate the costs of overseas service.** Precedence and area coverage are directly linked. Nearly 80 percent of the area-plus and 91 percent of the global lines are of precedence above priority while only 9 percent of the CONUS lines are of precedence above priority. These differences in precedence are reflected in large relative differences in the charge per line as compared to the charge per weighted unit. The charge per *weighted unit* for a global line is five times that for a CONUS line, but the average charge per global *line* is 15 times that for a CONUS line. High precedence is required to make overseas calls but service is much worse than for lower precedence area calls.

**The current rate structure could easily be adjusted so that, on average, the costs of different kinds of service would**

be borne by the users of that service. The adjustment could be made in a number of different ways. The text illustrates one method which involves calculating a new charge per weighted unit while retaining the cost ratios assigned to lines of different precedence. With the new, hypothetical charges, area costs would be paid for by area subscribers and overseas costs would be borne by those with overseas capability.

**One-way-in lines should bear some of the backbone costs.** Adding a one-way-in line to an installation that already has two-way lines increases the capacity both to take calls off the network and increases the capacity to place outgoing calls. It thus provides two-way line capability. Theoretically the zero backbone charge provides a much greater incentive for users to substitute a one-way-in line for a two-way line (and thus save nearly $3,000) than to add a new line (and incur costs of $2,600).

## B. USAGE-SENSITIVE PRICING

Usage-sensitive pricing has four basic objectives:

(1) To induce subscribers to choose the number of access lines and precedence that best suits their traffic requirements.

(2) To provide incentives for efficient use of the system.

(3) To allocate the costs of the system to the agencies that use it; the billing should also provide information that will permit agencies, if they wish, to shift the costs to or impose controls or regulations on the individuals or agency subdivisions doing the calling.

(4) To provide reliable information to the supplier of the service upon which to base decisions about how much capacity is required.

The following observations indicate how usage-sensitive pricing can be expected to aid in the achievement of these four objectives.

If the monthly backbone charge is very low and nearly all revenues are collected through usage charges, the number and mix of access lines will be more nearly optimal than if connectivity fees are high. At present, users must pay the same amount whether they use a line heavily or very little. Deciding to add one more line requires budgeting a significant amount of money. As a result, they are more likely to accept a higher level of congestion before acquiring a new access line than they would if access costs were near zero and revenues were collected for usage. In addition, if usage charges were instituted, the rationale for differential charges for two-way and one-way lines would disappear. Selection of the proper mix of lines then would be based upon the technical requirements of the user rather than artificial price differences. The resource cost of adding a line would be paid through access fees. The cost of using it would be paid through usage charges.

Charging for usage on the basis of distance, holding time and precedence would allocate costs equitably to each user agency. Adjustments to the present charging system would make it possible to allocate the total costs of a particular category of service, e.g., CONUS, to the entire group of subscribers using that service. Each subscriber would still not be paying his share, however. Only usage charges will permit allocation of costs properly to individual agencies or individual lines. Usage charges would also permit agencies to impose valid controls or restraints on callers. With the current charging system there is little justification or incentive to do so.

Charging for usage would provide incentives for callers to make fewer and shorter calls, thus reducing congestion costs and possibly reducing backbone costs. The degree to which such a result might be expected depends, of course, upon the policies user agencies follow in response to the bills it would receive from DCA.

If user charges are zero and all revenues are collected through connectivity fees, the service supplier has imperfect information upon which to base decisions on the amount of capacity to provide. If there is congestion, it derives from calls that would not be attempted if they were properly charged for. If there is no congestion with zero user fees, there is almost surely excess capacity. Thus, the level of congestion is not a valid standard against which to measure the adequacy of capacity. This point has little relevance for the overseas network where capacity is fixed and independent of congestion. In CONUS, however, capacity is adjusted on the basis of a target level of congestion. But this target level is arbitrary and has no relation to an optimum grade of service. If user charges were instituted, the grade of service would be a more meaningful indicator of congestion costs.

When user charges are zero, total costs, including congestion costs, will exceed the total costs incurred when appropriate usage charges are instituted. The real cost of supplying a given quantity of service is virtually fixed, but as the price per call charged the user falls below the marginal cost, more low valued calls will be attempted and the congestion costs imposed upon all callers, particularly those with high valued calls, will increase.

The existence of precedence capability reduces the cost of congestion by assuring that high valued calls are successfully placed. It introduces another cost, however, that is imposed upon those whose conversations are interrupted. The introduction of usage charges for precedence calls would allow the direct costs of precedence calls and the indirect cost of interruptions to be allocated to callers not just on the basis of capability but also as a function of how many high precedence calls they make. Charging for precedence calls would provide an incentive to select lower precedence for calls of lower value.

Charging for usage would permit the costs of overseas calls to be allocated to overseas users, regardless of precedence. With the current price structure, most of the cost of providing overseas service is collected through precedence charges. Usage charges based on time and distance would not only allocate costs correctly to individual users, but would lead to better allocations of overseas trunk capacity. It would also provide a basis for judging whether that capacity is adequate.

In imposing usage charges, DCA could (a) improve the equity of cost allocation, (b) influence agencies in their choice of numbers and kinds of access lines, but (c) affect only indirectly the behavior of callers. DCA's responsibility is limited to the backbone portion of AUTOVON. It has virtually no control over any activities outside the backbone. Thus, its pricing policies directly affect only the decisions made at the agency level. Effects upon caller behavior would depend upon agency response to the prices they face. The agencies could use discipline or budgetary procedures to influence callers if they wished to do so.

Preliminary estimates of the per minute charges that would cover the cost of calls within CONUS indicate that the user fees required would be considerably below those for FTS and commercial services. For example, our estimated charge per minute for a call of greater than 1,000 miles is 11.1 cents; that recommended for FTS in a recent study done for GSA was 23.9 cents.

The observations above relate exclusively to the pricing of the AUTOVON system as it is currently constituted. No attempt has been made to do an extensive study of AUTOVON nor to take into account the availability and costs of alternatives available to users such as dedicated lines. We have also ignored the existence of that portion of AUTOVON which is financed through procurement rather than lease. Procurement costs never show up in the annual budget figures and as a result are ignored in

calculating charges. In fact, there are a number of questions that have come up in the course of this study that should be answered before strong recommendations about pricing procedure can be made.

(1) What advantages and improvements in efficiency would accrue to the government from giving DCA control over the configuration and pricing of access lines as well as the backbone?

(2) What is the best way to price currently for connectivity to the backbone so that the costs of various types of service are allocated as fairly as possible to its users?

(3) What is the optimal way to price one-way and two-way lines?

(4) What is the magnitude of the congestion costs that system users now support, both for overseas service and for area service?

(5) What is the magnitude of the problem of pre-emption, both in terms of the number of calls pre-empted at each precedence level and in terms of the cost to the caller of being pre-empted?

(6) To what extent are user agencies interested in obtaining more detailed information on the number of calls made and the costs of calls made by individuals or organizations under their control? Would they use this information, if it were available, to influence the behavior of callers and the costs incurred by the agency?

(7) Is it feasible and are there advantages to integrating AUTOVON with FTS and/or combining it with a network of direct leased lines and WATTS lines?

(8) What is the cost of instituting AMA? Would partial installation of AMA and gradual expansion of coverage be feasible and cost effective?

Once these answers are available, it should be possible to make recommendations buttressed by some objective, and possibly quantitative, evidence to support the analysis and observations we have made in this paper.

# Appendix A

# PRICING FOR DIRECTIONALITY

## PRICING FOR DIRECTIONALITY

There are two related questions that must be answered in determining the appropriate charges for one- and two-way lines. The first is--what is the effective capacity, both in and out, of any mix of one-way-in, one-way-out and two-way lines? The second is--given that each user knows the level and distributior of this telephone traffic, is there an access-fee-only pricing system which will lead each user to choose that combination of access lines which most efficiently satisfied his needs? If the answer to this second question is no, one must then seek to find the access fee pricing structure which minimizes, in the aggregate, the resulting distortions. As we say earlier, a charging system based on user fees should result in no inefficiency in the selection of lines.

The answer to the first question can undoubtedly be found with engineering models already developed which predict how much capacity, for both in- and out-traffic, will be available on any configuration of access lines.

It may be possible to obtain some information relevant to the second question through the use of an optimization model. When users select a combination of lines to satisfy their telecommunication needs, they explicitly or implicitly minimize costs subject to choosing equipment that will satisfy certain operational constraints. This problem can be made explicit, formalized in a mathematical model, and then examined to determine how an opti .al collection of lines will change for the individual user as the prices change. The problem can be run with different hypothetical prices and when the optimal

collection of lines corresponds to what is actually the least cost collection, taking account of congestion costs (if possible), one can assume the prices are the appropriate ones.

Such a model could be formulated as an integer programming problem in the following way:

Let:

$x_1$ = number of one-way-in lines

$x_2$ = number of one-way-out lines

$x_3$ = number of two-way lines.

$a_1$ = backbone costs of one-way-in lines

$a_2$ = backbone costs of one-way-out lines

$a_3$ = backbone costs of two-way lines.

$b_1$ = commercial lease and equipment cost of a a one-way-in line

$b_2$ = commercial lease and equipment cost of a one-way-out line

$b_3$ = commercial lease and equipment cost of a two-way line.

$f_1(x_1,x_2,x_3)$ = I = in capacity

$f_2(x_1,x_2,x_3)$ = 0 = out capacity.

$k_1$ = expected number of in calls/period

$k_2$ = expected rate of out calls/period.

The objective function would be

$$\text{Min:} \quad C = (a_1+b_1)x_1 + (a_2+b_2)x_2 + (a_3+b_3)x_3$$

Subject to:

$$f_1(x_1,x_2,x_3) \geq k_1 \tag{1}$$

$$f_2(x_1,x_2,x_3) \geq k_2 \tag{2}$$

$$f_1(x_1,x_2,x_3) + f_2(x_1,x_2,x_3) = g(x_1,x_2,x_3) \tag{3}$$

$$x_i \geq 0 \text{ (all i)} \tag{4}$$

$$x_i = \text{integer (all i)} \tag{5}$$

The $b_i$ constitute the leasing and equipment costs the user must pay in addition to the backbone. The function $f_1(x_1,x_2,x_3)$, $f_2(x_1,x_2,x_3)$ indicates that the in-capacity and the out-capacity are both functions of the number of all three kinds of access lines. An additional out line creates in capacity and vice versa. Constraint (3), which contains both functions, merely indicat s that the sum of the two capacities is fixed. It may be that these functions can be designed to be linear. It may also make sense to set up the problem so that the constraints are met probabilistically rather than at all times.[1]

Another way to approach the problem of pricing different kinds of access lines is somewhat similar but would not require a programming model. One could analyze the problem not as one in which individual lines are considered to have some special characteristics, but as one in which a portfolio of lines has certain capabilities with individual lines priced on the basis of what they add to portfolio. The analogy is asset pricing in capital markets where assets are theoretically priced in terms of what they contribute to a diversified portfolio rather than on the basis of their individual projected income streams. For example, consider the four possible configurations using just two lines that provide both in and out capability; (1) one-way-in plus one-way-out, (2) one-way-in plus two-way, (3) one-way-out plus two-way, and (4) two-way lines. We present a simple table to illustrate the range of capacities in each case.

[1]If such a model can be built and the appropriate functions estimated, it may be a useful tool in looking not only at the appropriate selection of prices for access lines but also the appropriate prices for precedence and the effect of various kinds of user charges on the optimal mix of lines.

| Combination | Lines | | | Capacity | | Present Cost |
|---|---|---|---|---|---|---|
| | In | Out | In/Out | In | Out | |
| 1 | 1 | 1 | | 1 | 1 | 2 |
| 2 | 1 | | 1 | 1-2 | 0-1 | 3 |
| 3 | | 1 | 1 | 0-1 | 1-2 | 1 |
| 4 | | | 2 | 0-2 | 0-2 | 2 |

The numbers under the heading *Capacity* in the table indicate the range of available capacities for a combination of lines. Combination 3, for example, could provide from zero to one in-lines and from one to two out lines. It is evident that combination 4 is the most flexible since it could make available from zero to two lines for either in or out traffic. It thus includes all the other possibilities and for that reason should be the most valuable to the average subscriber. The technical desirability of the combinations for the average subscriber probably tends to increase in the same order in which they are listed in the table; combinations 2 and 3 include 1 as a possibility, while 4 includes all the lower ones.

The present costing system in no way reflects this technical ranking, however. The least desirable and the most desirable combinations are equal in cost, while combination 2 is higher and 3 is lower. Although combination 3 offers less flexibility in capacity than 4, it is sufficiently cheaper so that it would undoubtedly receive a higher economic ranking by many subscribers. Combination 2 would be chosen only by someone with special requirements that made him willing to pay the high cost.

The sample given is only illustrative. Any combination of larger numbers of lines can be defined in a similar two-parameter fashion in terms of the range of in and out capacity that it offers. Each combination can be normalized so that the range for its in-capacity and out-capacity lies between zero and two and

the combinations ranked according to their technical desirability. It may then be possible to estimate some prices to attach to the three types of access lines which would cause the cost combinations to reflect their technical value. It may turn out that since the price charged by a common carrier for all lines is the same, their costs to subscribers should also be the same.

# Appendix B

## DATA ON AUTOVON

## DATA ON AUTOVON

Several reports provide data that may be of value in estimating AUTOVON system usage by various subscribers. They are not comprehensive; the data they provide can be used to calculate the AUTOVON bills of various subscribers under different cost allocation schemes.

### A. OVERSEAS

There are a number of devices attached to switches that measure traffic on trunks and other equipment. Among these are the traffic usage recorder (TUR), switch memory peg count registers, and electromechanical peg count meters.

### B. TRAFFIC USAGE RECORDER

The traffic usage recorder is a continuous recording, direct reading device that monitors groups of trunks, equipment and access lines.[1] It scans the lines at fixed intervals (1 second, 5 second, or 10 second) and increments a meter each time it encounters a busy line. The accounting unit is termed a "unit call" and is composed of 100 call-seconds. If the TUR is scanning one line each second for one hour, the maximum number of positive counts would be 3600 or the equivalent of 36 unit calls. The percent occupancy of the line would be determined by dividing the actual number of busy lines encountered during the scanning period by 3600 or, equivalently, by dividing by 36 the number of unit calls recorded. The process is the same if lines are being

[1]Reference Vol. IX, Subsec. 701, p. 1-2, *DCA Traffic Engineering Practices.*

scanned every five seconds or ten seconds except that the number of busy lines encountered must be multiplied by five or ten to make the count equivalent to the one-second scan. With a ten-second scan, ten units of equipment may be monitored with a single register; five units may be monitored with a five-second scan, and one with a one-second scan.

The domestic data are reported in a computer output format--"AUTOVON Traffic Data Analysis Report, Voice Subscribers by Office," for which we have a copy only of the domestic information on access lines during a short period in 1975. These figures do not identify individual calls by origin, destination, or call length. If, however, it is possible to obtain (from other sources information on the distribution of calls according to distance and holding times, then the total usage figures in call units could be converted into calls by applying the appropriate distributions.[1]

## B. PEG COUNTERS

Peg counters are relatively unsophisticated instruments which simply record each time a particular event occurs. There are two types used in AUTOVON: a memory peg counter, which is part of the computer facilities of a switch, and a direct reading peg count meter, which is an electromechanical device. Data collected by the memory counter can be recovered and processed automatically. The electromechanical meters must be read and manually recorded.

Data are collected on interswitch trunk groups, PBX access line groups, and other trunks capable of both originating and terminating calls. There are four principal items of data collected: (1) Terminating Traffic Count (TM)--this scores when

[1] As will be discussed, all switchboards apparently submit to DCA something called an "AUTOVON Line Access Report" every six months that may contain some of the required information.

either a trunk or an access line is seized during either an idle or a pre-emptive search;[1] (2) Overflow Traffic Count (OVF), (OF), or (OFL)--this registers when a switch is unable to find an idle trunk or access line in a group (it is likely that an overflow will be registered before a pre-emption takes place); (3) Pre-empt Traffic Count (PRE)--this scores when a busy trunk or access line is selected on a pre-emptive search; (4) Originating Traffic Count (OR)--each request for originating service from a trunk or access line in a group scores without regard to whether the call is processed for service or ever goes beyond the first switch.[2]

These data are periodically collected on an hourly basis for all four-wire lines and for all PBX access lines. The termination and overflow figures are used to calculate the grade of service. The number of overflows divided by the sum of termination plus overflows gives the percentage grade of service. It is possible to calculate average holding time per call by dividing usage (obtained from the TUR) by the sum of originations and terminations for a particular PBX or 4-wire line (or groups of lines). If the distribution of holding times is assumed known (perhaps Poisson where the mean equals the variance) the distribution of calls by length would also be known for each access line (or group of lines). Given this distribution, it would be possible to calculate the changes associated with a particular cost allocation system simply by truncating the distribution at some point (number of seconds) below which it could be expected that calls would not have gone through, and then applying the changes, either per call or per minute, to those remaining.

---

[1]When the trunk seized is another interswitch trunk, rather than a termination trunk, the term "outgoing trunk connection" (OTC) is used.

[2]When the call comes from an interswitch trunk group, it is scored separately and called an "incoming trunk connection."

In addition to the peg count and the traffic usage data, DCA receives information that is collected at PBXs. The information collected on operator assisted calls includes the origin and distribution numbers as well as the length of call and precedence. The actual availability of operator call tickets is not known but samples are taken at specified intervals (probably six months) and the data are submitted to DCA by each PBX as the "AUTOVON Access Line Performance Report." Even if not completely exhaustive, the information from these reports could be sufficient to obtain estimated distribution of call times and distances for both domestic and overseas calls.